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2 vols #2
2 v.

vols 8-9
(1898-1899)

12 v. pub
1892-1[illegible]

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THE

INCORPORATED INSTITUTION OF GAS ENGINEERS.

TRANSACTIONS, 1898.

EDITED BY

THOMAS COLE, Assoc. M. Inst. C.E.,

SECRETARY.

LONDON: E. & F. N. SPON, Ltd., 125 STRAND.

NEW YORK: SPON & CHAMBERLAIN, 12 CORTLANDT STREET.

1899

The Institution is not responsible for the statements made or the opinions expressed in the following pages.

LONDON: PRINTED BY WM. CLOWES AND SONS, LIMITED, STAMFORD STREET AND CHARING CROSS.

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(Incorporated 1890.)

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President.

GEORGE E. STEVENSON, Manchester.

Vice-President.

T. BANBURY BALL, Rochdale.

Ordinary Members of Council.

CHARLES E. BOTLEY, Hastings.
WALTER W. FIDDES, Bristol.
WALTER R. HERRING, Edinburgh.
FRANK LIVESEY, London.
FREDERICK D. MARSHALL, Copenhagen.
THOMAS MAY, Jun., Richmond.
ARTHUR C. McMINN, Kensal Green.
FLETCHER W. STEVENSON, Sheffield.
JOSEPH TYSOE, East Greenwich.

Honorary Councillors—Past-Presidents.

CHARLES C. CARPENTER, Vauxhall.
WILLIAM FOULIS, Glasgow.
CORBET WOODALL, London.

Trustees.

W. FOULIS. W. KING. G. C. TREWBY.

Auditors.

MAGNUS OHREN. ALFRED LASS & Co.

Bankers.

LONDON AND COUNTY BANKING COMPANY,
Westminster Branch, S.W.

Solicitors.

FIELD, ROSCOE, & CO., 36 Lincoln's Inn Fields, E.C.

Secretary.

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PAST PRESIDENTS.

1891 GEORGE CARELESS TREWBY.
1892 CHARLES HUNT.
*1893 JOHN METHVEN.
1894 ALFRED COLSON.
1895 CHARLES CLAUDE CARPENTER.
1896 WILLIAM FOULIS.
1897 CORBET WOODALL.

* Deceased.

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The Incorporated Institution of Gas Engineers.

EIGHTH ANNUAL MEETING.

HELD AT THE OFFICES OF THE INSTITUTION, 11 VICTORIA STREET, WESTMINSTER, S.W., *February 26th*, 1898.

MR. CHARLES C. CARPENTER, Past-President, in the Chair.

THE Ballot Lists were handed to and examined by the Scrutineers, who reported the following gentlemen elected:—

As President—Mr. George E. Stevenson; as Vice-President, Mr. T. Banbury Ball—As Members of Council, Messrs. W. R. Herring, F. Livesey, F. D. Marshall, and J. Tysoe.

As Auditors—Mr. Magnus Ohren and Mr. Alfred Lass.

As Members—Messrs. H. T. Armitt, R. Brown, J. W. Buckley, J. R. Heath, S. Simmelkjær and J. M. Thomas.

The Report of the Scrutineers, having been moved and seconded, was duly adopted.

The Meeting was then declared adjourned to the 14th of June, for the reading of Papers, and the remainder of the business.

ADJOURNED EIGHTH ANNUAL MEETING.

HELD AT THE ROYAL UNITED SERVICE INSTITUTION, WHITEHALL, S.W.

June 14th and 15th, 1898.

MR. GEORGE E. STEVENSON, President, in the Chair.

THE following Report of the Council, having been printed and circulated among the Members, was taken as read:—

"The Council have the pleasure to record in their Eighth Annual Report, that the increase in Membership during the last twelve months has been the largest since the formation of the Institution. It will also be seen by the Balance Sheet, that the Institution's financial position is in a satisfactory and improving condition.

"Its usefulness is not less progressive; and the record contained in the last volume of 'Transactions' may fairly be considered conclusive of the position it occupies in relation to the Profession it represents.

"The Spring and Autumn visits have now attained an important place in the work of the Institution, alike in broadening the knowledge of contemporary Gas Engineering practice, and in bringing the Members together for mutual intercourse.

"The Autumn visit of 1897, inaugurated at Amsterdam, and extended through some of the chief cities of Holland and Belgium, was unique in its character; and the Council desire to take this opportunity of recording their appreciation of the great hospitality and kindness extended to the Members on every hand.

"The Spring Meeting has this year been arranged a month later than usual, in order to meet the convenience of the Dutch Institution of Gas Engineers, who will visit England in June. The Council have spared no effort to make their reception

worthy of the example set in Holland; and they would ask the co-operation of every Member in promoting a hearty reciprocity of good fellowship and good will.

"The First Report of the Committee appointed to consider the question of 'Standards of Light' and 'Correction for Gas Temperature,' has been circulated among the Members, and will be found a valuable and comprehensive *résumé* of a subject so vitally important to Gas Engineers as that of a reliable Photometric Standard.

"The Second Report, which deals with the question of Gas Temperatures, and will be found of great practical value, will be presented at the forthcoming Meeting.

"Seven admission applications from Students were made last year.

"Students of the Institution have privileges which should be a great boon to the younger Members of the Profession; and the Council again urge Members to assist their endeavour to obtain a large accession of numbers to this class.

"The Council record with deep regret the death of Mr. John Methven, of Beckton, and of Mr. Frank Mead, of Sutton.

Mr. Methven was an original Member and a Past President of the Institution, to the usefulness of which he greatly contributed.

"The Accounts to 31st December, 1897, have been duly audited, and the Balance Sheet is appended hereto.

"The Council have suggested certain modifications in the Articles of Association, and for the purpose of considering the same a Special Meeting will be held at the close of the Annual General Meeting."

On the motion of the retiring President, seconded by Mr. R. O. Paterson, the Report of the Council, together with the Statement of Accounts, was formally adopted.

The Scrutineers reported that the following gentlemen had been elected to the Institution:—

As Members—Messrs. T. Berridge, R. Beynon, T. Crossley, J. Drory, G. F. L. Foulger, G. Helps, H. H. Jones, and A. Kitt.

As Associates—Messrs. F. H. Arnold, J. D. Ashworth, and P. C. Hunt.

Mr. Woodall then introduced his successor, Mr. George E. Stevenson, who took the Chair amid applause.

UNIV. OF CALIFORNIA

It was proposed by Mr. George Livesey, seconded by Mr. T. May, and carried by acclamation, "That the best thanks of this Meeting be given to Mr. Corbet Woodall, the retiring President, for his services to the Institution during the past year."

The President then delivered his Address, for which, on the motion of Mr. G. C. Trewby, seconded by Mr. C. Hunt, a hearty vote of thanks was unanimously accorded.

The President presented the Second and Final Report of the Committee on the proposed Standard of Light and Temperature of Gas Measurement, together with the Report of the Sub-Committee.

A discussion followed, at the close of which, it was proposed by the President, seconded by Mr. S. Glover, and carried, "That the Reports be accepted and printed with the Proceedings, and that the thanks of the Meeting be given to the Committee for the pains they have taken in their preparation."

The following Papers were read and discussed:—

High-Pressure System of Distribution. By F. W. Stevenson.

Inclined Retorts. By E. Drory.

A Modern Gas-works. By F. D. Marshall.

On a Standard 10-candle Lamp. By Vernon Harcourt, F.R.S.

The 2-candle Standard. By E. L. Pryce.

A New Departure in Carbonising. By S. Glover and T. Glover.

Washers and Scrubbers. By E. A. Harman.

It was proposed by the President, and carried unanimously, "That Mr. A. E. Broadberry, T. S. Lacey and W. E. Price be elected Scrutineers for the ensuing year."

It was proposed by the President, seconded by Mr. C. Hunt, and carried unanimously, "That the best thanks of this Meeting be given to the Authors of the Papers."

It was proposed by the President, seconded by Mr. T. May, and carried unanimously, "That the best thanks of this Meeting be given to Mr. Magnus Ohren, the Honorary Auditor."

It was proposed by Mr. T. Holgate, seconded by Mr. E. A. Harman, "That the best thanks of the Institution be given to the Council for their management of its affairs during the past year."

On the motion of Mr. W. Foulis, seconded by Mr. J. W.

Helps, a hearty vote of thanks was accorded to the President for his conduct in the Chair.

In his response, the President proposed that the best thanks of the Meeting be given to the Secretary, Mr. T. Cole, for the manner in which he had performed his duties.

This was seconded by Mr. Glover, and carried unanimously.

The Annual Dinner of the Institution was held at the Trocadero Restaurant, Piccadilly Circus, on the evening of Tuesday, June 14th, the President occupying the Chair.

SPECIAL GENERAL MEETING.

HELD AT THE ROYAL UNITED SERVICE INSTITUTION, WHITEHALL, S.W., *June* 15*th*, 1898.

MR. GEORGE E. STEVENSON, President, in the Chair.

THE President proposed the following resolution, "That the Articles of Association be altered so as to read as follows:—

"ARTICLE 9.—There shall be a President, a Vice-President, an Honorary Secretary, and nine other Members of Council, all which twelve persons shall be chosen from the Members only. These, together with such Honorary Councillors as hereinafter provided—being not more than fifteen persons in all—shall constitute the Council to direct and manage the concerns of the Institution. &c. &c.

"37.—The elective Members of Council other than the President, Vice-President and Honorary Secretary, and hereinafter called "Ordinary Members," who are to retire in each year shall be chosen by rotation, or, in cases of equal seniority, as may be determined by ballot amongst themselves. Such Members shall be ineligible for re-election during the following year. The Honorary Secretary shall retire annually and shall be eligible for re-election.

"41.—The Council shall, previously to the Annual General Meeting in each year, prepare a list of persons whom they nominate as suitable for the offices of President, Vice-President, Honorary Secretary, and the ordinary Members of Council, whose offices will be vacant, and Auditors for the ensuing year. &c. &c.

"42.—In case, for any reason, or by inadvertence, the election of President, Vice-President, Honorary Secretary, Members of Council or Auditors, shall not be made at the General Meeting, &c. &c.

"44.—The President, Vice-President and Honorary Secretary shall be ex-officio Members of all Committees of the Council, and the President shall take the Chair at all the Meetings of

the Institution, the Council, and the Committees, at which he is present.

"46A.—The Honorary Secretary shall perform such duties and shall exercise such control over the Secretary as may from time to time be prescribed by the Council.

"49.—Without limiting or controlling the effect of the preceding Article, the Council may—

"(*a*) In case of any casual vacancy occurring in the Council (otherwise than in the case of the President or Vice-President), whether owing to death or resignation or any other cause, elect a Member to fill any such casual vacancy; but the person so elected to fill up any such vacancy shall continue in office so long only as the person in whose place he shall have been elected would have been entitled to continue if he had remained in office; and in case of any casual vacancy occurring in the office of President, Vice-President, Honorary Secretary or Secretary, between two Annual General Meetings, appoint some person to fill such office (being in the case of the office of President, Vice-President or Honorary Secretary a Member), until the next Annual General Meeting or any intervening Special General Meeting convened for the purpose of such election: &c."

The resolution was seconded by Mr. Foulis and carried unanimously.

SPECIAL GENERAL MEETING.

HELD AT THE OFFICES OF THE INSTITUTION, 11 VICTORIA STREET, WESTMINSTER, S.W., *July* 13*th*, 1898.

MR. JOSEPH TYSOE, in the Chair.

AT a second Special General Meeting, held as above, it was proposed by the Chairman, seconded by Mr. T. S. Lacey, and carried unanimously, "That the Resolution as passed at the Special General Meeting on the 15th June be confirmed."

SPRING MEETING.

RECEPTION AND ENTERTAINMENT OF THE DUTCH GAS ENGINEERS—VISIT TO THE EAST GREENWICH GAS-WORKS, ETC., *June* 16*th*, 1898.

THE Institution received and entertained the Members of the Dutch Institution of Gas Engineers, the programme of whose Annual Meeting included a visit to London. Favoured by delightful weather, the entertainment of the Continental visitors was a complete and enjoyable success. The Dutch engineers were received and welcomed by the President, Mr. George E. Stevenson, on board the steamboat *Alexandra* at Westminster Pier, and a river excursion was made the opportunity of witnessing the sights of the Thames, including the Houses of Parliament and the Tower Bridge, the bascules of which were opened on passing. Luncheon was served on the deck of the steamer. The river journey was continued a little beyond the Beckton Gas-works (which were visited on the following day); and, in passing and repassing, the coal-handling machinery in operation there was the centre of attraction. On the return journey a stop was made at Greenwich, to inspect the East Greenwich Gas-works of the South Metropolitan Gas Company. Mr. George Livesey, Chairman, Mr. Frank Livesey, Mr. Tysoe, and the other engineers of the Company, conducted the visitors over the works and explained the various points of interest. The tour of inspection was much assisted by the following description of the works, which was printed in Dutch and English for the guidance of the visitors:—

"When the South Metropolitan Gas Company amalgamated with the Phœnix Gas Company and the Surrey Consumers' Gas Company, it was evident that some provision must be made for the ordinary growth of the business, as it was considered at that time that the existing plant was working up to its full capacity. Further, when two small gas companies supplying Woolwich were absorbed, it became more than ever necessary.

"Accordingly, 127 acres of land were purchased in the Greenwich Marshes, having a frontage of 1400 yards to the River Thames.

"Some 96 acres of this land were reserved for gas-making purposes, upon which area it was originally intended to arrange for a make of 60 million cubic feet per diem, with twelve retort-houses. Three retort-houses, 485 feet long, running parallel with the river, are now completed, with a fourth in progress—all in one block, each house being equal to a make of 5,800,000 cubic feet per day, having 45 settings of ten retorts in a setting, making in all 1350 retorts, 20 feet long, producing 17½ millions per diem.

"Each retort-house has separate connections, condenser, exhauster, washer, scrubber and purifiers, with one extra set of exhausters for three retort-houses.

"In No. 1 retort-house the Foulis-Arrol hydraulic stoking machines are used. Each set of machines will draw and charge 900 mouthpieces in the 24 hours.

"In No. 2 house, West's stoking machines are used. These will draw and charge 1080 mouthpieces in the same time. They are worked by the wire-rope system, driven by a gas-engine.

"The coal jetty is built L-shaped, with the intention of adding another arm when the business requires it. At present four hydraulic cranes are fixed for unloading only one ship at a time. The jetty is in communication with the coal stores between each retort-house, by means of an elevated railway. A ship of 1250 tons is discharged in about 7½ hours.

"The gas is condensed in pipes running round the retort-house, and afterwards in a 36-inch spiral pipe-condenser. It then travels through a water condenser, so arranged that the gas passes backwards and forwards through the gas passages, while the water runs from bay to bay in the opposite direction.

"A 16 horse-power compound condensing engine is connected direct to two 125,000 cubic feet per hour exhausters. There are four of these sets; one set for each retort-house, with one spare set for the three houses.

"The gas passes through three 'Livesey' washers supplied with ammoniacal liquor from the hydraulic main and scrubber, and thence to the scrubbers—the second and final one supplied with water which is pumped over and over in the first or liquor scrubber.

"There are six purifiers—four charged with lime and two with oxide. The lime purifiers are worked in rotation, three only being as a rule in operation, the remaining one to put on when the first one has done its work. The second and third purifiers in the series are the ones that remove the sulphur compounds; the first purifier often showing a larger quantity at the outlet than the inlet. The purifiers of the first set were 67 ft. 6 in. by 30 feet, or 2025 square feet area, or 383 square feet per million cubic feet of gas made per diem. In the second set, the purifiers were made larger; giving an area of about 470 feet per million per diem. The experience gained by these different areas is that, though large purifiers may be economical for the removal of sulphuretted hydrogen when oxide only is used, they can be made too large for the efficient removal of sulphur. The temperature of the boxes should be well kept up—an easier task with small boxes; and with this view better work will be done if the purifiers are under cover.

"The station meters will pass 150,000 cubic feet per hour; two being required for each retort-house. The drums work in concrete tanks, sunk in the ground, so saving the expense of a meter-house.

"The first gasholder erected is in four lifts, varying from 241 to 252 feet diameter, and 44 feet deep, with a capacity of 8,080,000 cubic feet. The second gasholder built was made larger; but as the water in the ground was the cause of adding so considerably to the cost of the work, it was decided to excavate to a depth of 13 feet only, carrying the concrete tank 20 feet above the ground level. As the diameter of the outer holder is 300 feet, and the depth only 31 ft. 6 in., the holder would be difficult to guide on rising unless special care had been taken in the arrangement of rollers for the inner lift. There are six lifts, two of which rise above the framing. The capacity of the holder is 12,100,000 cubic feet.

"A considerable portion of the gas made at these works is sent up daily to the Old Kent Road Works through four miles of 48-inch main. During a few of the winter months the gas is pumped; but for the remainder of the year, the gasholders at East Greenwich being heavier than the Kent Road holders, gas can be delivered in sufficient quantities without using an exhauster.

"Plant for the manufacture of sulphate of ammonia has

been erected, capable of making 60 tons of sulphate per week. This is now being extended so as to be capable of making 150 tons. A 'Claus' sulphur recovery plant was built to deal with the sulphuretted hydrogen. As, however, the adjoining sulphuric acid works have recently been purchased, the sulphuretted hydrogen is now burnt into sulphuric acid, travelling a length of 600 yards.

"The chemical works just mentioned only came into possession of the company last March; so the very poor state of repair into which they have been allowed to fall must not be put to the credit of the company or its officers. The works, though dilapidated, are capable of making a considerable quantity of sulphuric acid at a low figure; and as about 4000 tons of acid is required yearly, some considerable benefit will be obtained. The acid is chiefly made from sulphur ore obtained from Spain, added to by the sulphuretted hydrogen from the sulphate works. Furnaces will shortly be erected for burning the spent oxide. The plant, when repaired, will be capable of making 160 tons of acid per week."

The party left the boat at Greenwich, and proceeded by a special train to the Crystal Palace, where the visiting engineers were entertained by the Institution to a banquet in the large summer dining hall. Mr. Stevenson, the President, occupied the chair. Later in the evening the glories of the fireworks were witnessed with much delight.

On Friday, the 17th June, the Dutch engineers proceeded by special train to Beckton, where they were received and entertained to luncheon by the Gas-Light and Coke Company, after making an inspection of the various sections of the gas- and products-works.

AUTUMN MEETING.

Visit to the Manchester Corporation Gas-works, *September 29th*, 1898.

At the invitation of the President, Mr. George E. Stevenson, the Autumn Meeting was held in Manchester.

The Members, accompanied by the President, first drove to the Bradford Road Works, over which they were conducted by Mr. Stevenson and the general staff, who did their utmost to make the inspection an instructive one. The retort-house machinery, and the method of removing and stacking the coke in the yard, were particularly noted, and great interest was manifested in the water gas plant. After a few kind words from the Chairman of the Committee of this station, the party proceeded to the Gaythorn Works, which were also thrown open for inspection. Apart from a general tour of the works, attention was here chiefly directed to an installation of inclined retorts which had been constructed in a house originally planned for the horizontal system. Very complete arrangements had been carried out for unloading and conveying the coal to the charging hoppers, and for removing the coke as discharged from the retorts, the drawing and charging of a number of which was witnessed.

The Members were then entertained at luncheon at the Town Hall, where they were welcomed by the Lord Mayor of Manchester, whose hospitality was much appreciated, the President thanking him, on behalf of the Institution, for his generous reception and welcome to Manchester.

The rest of the day was well spent in visiting the engineering works of Messrs. Mather and Platt, and one of the largest spinning and weaving mills in the neighbourhood. At the engineering works an opportunity was afforded of seeing the construction and details of a large quantity of electric and other machinery; and at the mills the whole process of the

conversion of the raw cotton into finished fabrics was brought to the notice of the party.

The following day was devoted to an excursion to the Lake district. The Members proceeded by train to Windermere, where, after luncheon, they embarked on a steamer and made a complete tour of the lake, afterwards partaking of tea together, when acknowledgment was made of the kindness of the President in arranging a most successful meeting and enjoyable excursion.

THE PRESIDENTIAL ADDRESS.

By GEORGE E. STEVENSON.

It is with a profound sense of the honour you conferred upon me, by electing me your President this year, that I rise to address you this morning.

To-day the Institution meets again in the eighth year of its existence. Our numbers have increased year by year, and now exceed 200 Members. Although still not a very large body, we represent a very important section of the gas industry of the United Kingdom. The gas undertakings represented by our home Members manufacture some 83,000 million cubic feet of gas per annum; this being equal to 65½ per cent. of the total output in Great Britain and Ireland. We have also enrolled among our Members the Engineers of some very important Continental and Colonial gas-works.

Though only eight years have elapsed since the Institution was incorporated and commenced its career, it has already accomplished much useful work. By papers and discussions at our meetings, the value of modern improvements in carbonising plant, and in machinery connected therewith, has been emphasised. Special attention has been given to new methods of gas making, and to the recovery of additional bye-products resulting therefrom. A special Sub-Committee of the Institution have carefully tested a proposed photometric standard, and determined its relative value. They have also studied the question of temperature as affecting the percentage of unaccounted-for gas, and approximately defined the lines upon which corrections for temperature should be made in the registration of the station-meter, in order to correspond with the temperature at which the gas is sold. The Institution has discussed the relationship of gas workers to their employers, and shown how, in one instance at any rate, a happy solution has been found for the difficulties that existed. The Institution has not confined

its attention solely to the phases of gas-works management in Great Britain, but has sought acquaintance with the aspect of things on the Continent; visiting last autumn cities in Holland and Belgium, where the members received the greatest courtesy and kindness from their fellow Gas Engineers in those countries. The return visit of the Dutch Association of Gas Engineers to London this week, will afford the Institution an opportunity of reciprocating the courtesies shown to the Members last year, and of cementing a friendship so happily begun on the other side of the Channel.

In some respects, our meeting this year cannot be said to be inaugurated under quite such rosy auspices as in 1897. We have to deplore the loss of two Members through death since we met last year—one a very prominent Member, and a Past-President of the Institution, whose place amongst us cannot easily be filled up. We are powerless to prevent these sad occurrences; but when they occur, let us brace ourselves to maintain the reputation of the Institution for energetic and useful work as the best antidote to the inroads of the Great Reaper. More especially let us look to the younger Members of the Institution to keep alive the originality of our proceedings, and give them every possible encouragement to impart their views and describe their experiments. To the younger men will fall the work of improvement and progress in the future; and, while a ripe experience is not to be undervalued as a guiding and correcting influence, the new hands are those most fitted, and most free, to develop the new ideas, and bring them to a practical issue.

Last year we met fresh from the realisation of a great increase in the annual consumption of gas, which induced sanguine expectations of rapid augmentation in the extent and importance of our gas undertakings. This year, we come together in the knowledge that, temporarily, these expectations are not to be realised. The fickle climate under which we in Britain are placed, has ordained that an unusually mild winter should put a restraining hand on the demand for gas; and in some of the larger undertakings the consumption has remained more or less stationary in the past year.

The serious and prolonged strike in the engineering trades, which lasted from July 1897 till February 1898, was not without an important influence on the progress of the gas

industry. It deprived us of many sources of gas consumption, and otherwise affected us prejudicially in delaying the execution of contracts for ironwork and machinery required for last winter's work. The strike directed afresh the attention of the public to the seriousness of the labour question; and it was felt more than ever that steps must eventually be taken to bring about a community of interests between employer and employed. In all branches of employment, there is still far too much of the old idea that the person employed is in some sort of sense a chattel of the employer; and, though the British workman has to a large extent succeeded in emancipating himself from this bondage, he is yet almost universally in the position of being eventually used up by the system under which he works, without having the chance of sharing in the prosperity which his labour has created, or reaping any after-benefit from his years of service, when his powers as a worker fail. So long as the worker has no direct interest in the prosperity of the undertaking he works for—be it a private enterprise or a public concern—it is not surprising if he seeks his own immediate benefit, even though it be at the cost of ruining the industry with which he is identified. Once let him, however, be placed in the position in which he can see that his own interest and those of the business are identical, and he will think for the future as well as for the present, and a common ground will be established. That such a condition of things may be brought about by a judicious application of the profit-sharing principle, has already been proved in more than one class of industrial enterprise.

A strike of workmen invariably gives increased force to the arguments in favour of the adoption of machinery for all mechanical purposes. It is not that there is any aim to ultimately reduce the number of workers, but that a way may be found to, in some degree, accord to them the remuneration and the comfort they desire, without at the same time handicapping the industry with an increased cost of production. Thus, in gas-works the adoption of machinery for handling the raw material and solid bye-products is becoming more and more universal. In small undertakings, the Committees and Boards of Directors are now found willing to spend large sums of money on means to effect this—in some cases, it may be, without due

regard to the return that may be expected, but always with a view to diminish the multiplicity of hand labourers engaged in unintelligent operations, and increase the status and responsibility of the workmen.

As a necessary consequence of the fulfilment of these aims, the capital cost of installations of new carbonising plant has increased, while the working expenses have diminished. There is nothing surprising about this, for, in the first place, whatever current expenditure is saved by transmuting the energy employed in mechanical operations from manual power into power exerted by machines, must in the process of conversion be capitalised; and, secondly, as the interest payable on capital becomes less and less, so it becomes more and more advantageous to capitalise the expenses. At the present day, the cost of equipping a large retort-house with modern regenerator settings, power machinery for stoking, and machinery for elevating and conveying the coal and for removing the coke, amounts to about 100*l.* per mouthpiece. This cost may be roughly divided as follows:—

	£
Retort-house with stage-floor	35
Retort-settings and fittings, including chimneys	40
Stoking-machines and coal-elevators, &c.	15
Coke-conveying machinery	10
Total	£100

Inasmuch, however, as a greater duty is obtained from modern plant in gas production per mouthpiece per diem, the cost of construction has not been proportionately increased in relation to the producing capacity; and it may now be taken to be equal to about 12,000*l.* per million cubic feet per diem. But modern retort-houses perform their work at much lower cost for labour than the old description of plant. What formerly cost 3*s.* per ton of coal carbonised, is now done by machinery for 1*s.* 9*d.* per ton. This means a saving of 1250*l.* per annum for every million feet of daily productive capacity.

The lowest estimate I have seen for the cost of a ground floor retort-house worked entirely by hand is 8000*l.* per million per diem.* Taking this as the standard of cost of the earlier

* See H. E. Jones, 'Proceedings of Civil Engineers,' 1875.

type of retort-house, the saving effected by the application of modern machinery yields a return of 30 per cent. per annum on the increased capital expenditure. Besides this saving in the cost of manufacture, we have gained the advantage that from 30 to 50 per cent. more gas than formerly can now be produced on the same ground area.

The modification of the carbonising plant known as the inclined retort system has, during the past six years, gradually acquired importance, both in England and abroad. Accompanied in the first attempts by difficulties and disappointments, it has fought its way to a firmer position, and now bids fair to become more and more universally adopted. No doubt exaggerated claims have been made on its behalf; but it cannot, I think, any longer be denied that it possesses certain very definite advantages—more especially for works the magnitude of which is not sufficient for the full development of power-stoking machinery. Even in competition with stoking machinery, it is my belief that the inclined system is destined to display a distinct advantage. It is, perhaps, not at first quite easy to see wherein this advantage lies. There is the same retort area, with the same results in distillation; the same expenditure of energy is necessary to bring the coal to the retorts and remove the coke. Wherein, then, is a saving in labour to be effected? I have come to the conclusion that the source of further economy is to be found partly in the fact that the coal, once it is elevated and conveyed into position for charging into the retorts, does not again require to be moved otherwise than by gravitation, and that no power, other than the same force, is needed to bring the coke out of the retorts; and partly because (at least, if retorts 20 feet long are employed) an equal quantity of coal is charged in half the number of operations. It is evident that the cost of attendance ought to be less when the coal finds its way into, and the coke out of, the retorts by virtue of their own weight, instead of having to be lifted and conveyed by power into and out of the receptacles for distillation. The cost of wear and tear should also, under these circumstances, be reduced. That up to the present time no absolutely reliable proof has been forthcoming that inclined retorts possess this economical advantage over machine stoking, I regard as due to the fact that as yet no installations of in-

clined retorts have been worked on a sufficiently large scale, and under such propitious circumstances as have for some time past attended mechanical stoking.

The cost of constructing inclined retort-settings is certainly greater than that of horizontal settings. In fact, from my own experience, I should put it at 50 per cent. more for the settings themselves. But possibly some reduction may be expected in the reduction of the accompanying machinery. Should it be found, however, as I fully anticipate, that a reduction of 6*d.* per ton in wages over and above the saving which can be effected by machine stoking is to be realised, this additional saving will amount to 20 per cent. on the increased capital expenditure. One thing is certain about inclined retort-settings. They must be very carefully constructed, and very substantially braced by strong ironwork. Any neglect of these precautions is simply courting failure.

No radical departure from the usual type of carbonising plant has yet been introduced with success. Devices for the continuous carbonisation of coal in small quantities, constantly fed into retorts, have hitherto met with insurmountable difficulties, both in respect of the maintenance in good working order of the apparatus, and in the quality, and the means of removal, of the coke. Carbonisation in bulk has received some encouragement in the progressive types of coke-oven now in vogue—notably that known as the Semet-Solvay system, with internal heating flues. But in this type of oven the bulk of the material dealt with is to a great extent sacrificed to other considerations; and the actual result is a nearer approach to the masses of material we are ourselves accustomed to carbonise.

The cost of repairs on a modern gas-works of magnitude is enhanced by the multiplication of machinery effecting the various operations, but not to an extent that seriously affects the total working expenses. The following analysis of the expenditure under the head of wear and tear at a large works where the stoking is all performed by machinery may be of interest, as showing the proportion due to each of the different operations carried on. I will not tax your patience by reading over the items; but you will notice that stoking machinery costs slightly more than 2½*d.* per ton for maintenance.

ANALYSIS OF COST OF WEAR AND TEAR PER TON OF COAL CARBONISED AT THE ROCHDALE ROAD GAS-WORKS, MANCHESTER.

Coal delivery department, including railway lines locomotives, capstans, stages, steam cranes, &c.	0·84*d.*
Retorts—repairs and renewals of retorts and furnaces ..	6·66
Retort-fittings, including furnace fittings..	2·40
Stoking machinery, including elevators and conveyors, and engines working same	2·58
Tools—retort-house shovels, barrows, &c.	0·75
Sundries, in retort-house only	0·51
Boilers, including boiler fittings..	1·09
Exhausters, including engines and pumps	1·66
Condensers, washers and scrubbers	0·33
Purifiers, including lifting gear for covers and elevating machinery for oxide, &c.	1·05
Station meters, gasholders and governors	1·15
Workshops, including tools and machines in same	0·62
General (not applicable to above headings)	1·34
Total	1*s.* 8·98*d.*

Before leaving the subject of modern carbonising plant for coal gas manufacture, allow me to contribute one additional proof, to the many which have been adduced, of the value of the regenerative system of heating retorts. Up to the year 1891, the retorts at the Rochdale Road station of the Manchester Gas-works—numbering 1066 mouthpieces—were all heated by the old method of direct firing. The quantity of coke sold in the year ending March 1891 amounted to 6·67 cwt. per ton of coal carbonised. The reconstruction of the retort-settings was commenced in that year, by the erection of a bench having producers, but no regenerating flues. The result, so far as saving in fuel was concerned, was practically *nil.* Subsequently, regenerators were added to the same settings, and further reconstructions were undertaken in which the principle of regeneration was fully applied. Last year three-fourths of the retorts in use at the works were heated on this system; and the coke sold had risen to 8·78 cwt. per ton of coal—the increased sales in that year representing an additional quantity of 15,330 tons of coke, the revenue from which was, in round figures, 4000*l.* At the present time, all the retorts are on the modern system; and the works are now turning out 9½ cwt. of coke for sale per ton of coal and cannel carbonised. This, it should be noticed, is with a consumption of 40 per cent. of cannel, much of which produces little coke, of inferior quality.

The manufacture of carburetted water gas is a development which has already obtained considerable extension in the more important gas undertakings in Great Britain. As an instrument for the enrichment of coal gas, it has proved itself more economical than cannel under existing prices of oil. An analysis of the working expenses at Manchester, extending over four months of last winter's work, gave a net cost into the holders for 25-candle carburetted water gas of 1*s.* 1·65*d.* per 1000 cubic feet. It would certainly not have been possible to make 25-candle cannel gas at this price. When mixed with coal gas to the extent of 25 per cent. of the total, no inconvenience has been experienced from the greater density of the gas, nor has any complaint whatever arisen among consumers which could be traced to the admixture of water gas. It may be doubted whether the supply of carburetted water gas alone, or even as the greater proportion of the total, is desirable or prudent in this country. If, for this purpose, the water gas be made of lower illuminating power, the same advantage in cost price is not maintained. Water gas of 20-candle power costs only 2*d.* per 1000 feet less than that of 25-candle power; the difference being merely due to the lesser quantity of oil consumed. Though the opinion of experts has been freely given in favour of the harmlessness of supplying water gas, there are not wanting signs, even in America, of a tendency to restrict the supply of the unmixed gas. The inquiries made at Boston, in the United States, show that a feeling exists that the percentage of carbon monoxide in illuminating gas should be kept within certain limits.

The advantages of a water gas plant in providing a means for the rapid augmentation of the gas production when required, has been frequently commented upon. It possesses also very important advantages in the lesser capital cost of the plant for a given make of gas, and in the comparatively small area of ground space on which plant of large productive capacity may be installed. As to the capital cost, it has been stated that carburetted water gas plant costs only half, or less than half, what coal gas plant costs. This I regard as incorrect. From the data afforded by our own experience in Manchester, I find the cost for all appliances up to, but exclusive of, the purifiers, to amount to two-thirds that of coal gas plant. In round figures, the cost is 15,000*l.* per million cubic feet per diem for coal gas, and 10,000*l.* per million cubic feet for water gas.

It has been assumed that the manufacture of carburetted water gas entails less expenditure on purifying plant than is involved in coal-gas making. This, I think, is wanting in confirmation. If the carbonic acid is abstracted, it is found necessary to have even more purifying area in proportion to the make of gas than is required for purifying coal gas from sulphuretted hydrogen alone.

Future designs for the extension on a large scale of carbonising plant will probably take the form of a combination of the inclined retort system for coal gas, with carburetted water gas as the principal instrument of enrichment. Such a combination possesses many advantages. The capital expenditure can be kept within reasonable limits by the lesser cost of the water gas plant; the productive capacity per unit of ground area will be at a maximum, and the working expenses at a minimum point. It must, however, not be forgotten that the cost of making carburetted water gas depends to a very large extent on the price of oil; the cost of the oil amounting, even at the present low prices, to over 70 per cent. of the total cost for gas of 25-candle power. A slight rise in the price of oil would therefore upset the balance of advantage; and it would not be wise to be dependent upon water gas to too great an extent.

During the past year, the attention of gas engineers in this country has been directed to two new possible methods of gas enrichment. One is that of returning a portion of the purified gas back into the crude and still heated gas; the theory being, it is assumed, that the addition of gas from which all condensable products have been abstracted, to the gas still charged with heavy hydrocarbon vapours, will enable the latter to retain certain hydrocarbons in suspension which otherwise would become liquefied. This process appears to have been carried on by Mr. Shadbolt, of Grantham, with success; and his results have recently received confirmation from an American source. The other method has arisen out of proposals emanating from Mr. Young, of Peebles, and Mr. Glover, of West Bromwich. These proposals, having for their primary object the elimination of naphthalene deposits, consist in the distillation of part of the coal or cannel at a low temperature, in order to produce a gas highly charged with illuminating vapours—which vapours the gas would not, if cooled and unmixed with other gas—be able to retain—and then mixing this gas with poorer gas produced

at a high temperature. Experiments made by Mr. Samuel Glover, at St. Helens, go to prove that this method has for its result a decided increase in the illuminating power of the combined gases, as well as an important effect on the deposition of naphthalene.

Both these departures from the ordinary methods of procedure open up a new phase of the question of the distillation of coal and cannel, and point to the desirability of a better understanding of the particular treatment required by different classes of material. Nothing can be more certain than the fact that, in carbonising a heterogeneous mixture of different kinds of coal and cannel under the same set of conditions, there results a loss all round of illuminating value. In large works carried on under such circumstances, the proportion of cannel required to maintain a certain illuminating power is much in excess of that which the value of the different materials, as revealed in experimental tests, shows to be really necessary.

In regard to the appliances for condensing, exhausting, washing and purifying gas, no important advances can be said to have been recently made. Endeavours to utilise the ammonia in the gas as an agent for the partial removal of the carbonic acid and sulphuretted hydrogen, have met with a large measure of success in the hands of Mr. Holgate; but the complete purification of gas by liquid reagents seems as far off as ever. Experiments made at one of the Manchester gasworks, with a view of reducing the sulphur compounds by washing the gas with ammonium sulphide, point to the necessity of saturating the causticised ammoniacal liquor with sulphur from some external sources, in order to produce a reagent sufficiently powerful, and in large enough quantity, to effect any important result.

Exhausting plant remains the same in character as heretofore. Having regard to the importance of securing a permanent relationship between the volume and speed of the gas passing through the purifiers and the area of the latter, it has often surprised me that in large works the exhausters are not so arranged that each separate stream of gas is driven by an independent exhauster, or set of exhausters, through independent washers, into separate sets of purifiers, instead of the division of the gas into two or more streams being made after the exhausting and washing apparatus has been passed. Such a

disposition of the plant would, it appears to me, ensure more complete control over the action and effect of the purifiers. It is possible that some of our London Members have carried out this idea unknown to me; but I have not seen a works where, to my knowledge, it is in practice.

Much the same must be said of the purifying plant as of the foregoing; it remains essentially what it has been for the last twenty years. Certain ingenious attempts have recently been made in America to obviate the necessity of opening purifiers when a change of material is required, and to effect this change by the successive removal and replacement of the material by mechanical means while still enclosed in the purifying vessel. Nor are there wanting proposals in this country for the construction of purifying machines in which the gas may be treated with the usual purifying agents on a continuous and automatic principle. To what extent the appliances devised for these purposes will eventually commend themselves, remains to be determined. However crude at the present moment, they may prove to be the germs of some very practical system to be developed in the future.

While the cost of carbonising plant has tended to increase, that for the storage of gas has diminished. Large gasholders are now the rule; and active spirits are still busy perfecting methods for safely dispensing with the guide-framing so long deemed to be necessary for the stability of this bulky apparatus. It must ever remain a matter of opinion whether the saving to be thereby effected in first cost is worth running any risk for; and it has yet to be proved—at any rate in the case of very large gasholders—that absolutely no risk is incurred by dispensing altogether with the guide-framing. The concentration of storage capacity in one, or at most two, large holders entails no anxiety in our days; and much advantage is found to be derived therefrom in the simplification of the connections, and generally in the working details, as well as in the reduced capital expenditure per million cubic feet capacity.

Of the distributory plant of gas undertakings we hear very much less than its importance demands. The mains and services, being placed out of sight, do not attract the same attention on the part of directors and committeemen as do the parts of a gas-works. Nevertheless, the capital invested therein is very considerable; and the well-being of an undertaking is

much influenced by the adequacy or otherwise of the provision made for delivering the gas to the consumers. In large cities, the difficulty of laying trunk-mains in the principal thoroughfares becomes more and more serious as these streets become the receptacles for electric cables, hydraulic pressure pipes, and other mediums of the supply of public conveniences. I am afraid that, for the most part, the system of gas-mains in our large provincial towns remains very much what it was in the early days of gas lighting, notwithstanding the immense extension which has taken place in the area of supply and in the volume of gas to be delivered. The number of leading mains proceeding out of the works has been multiplied; but the same principle of distribution has been maintained—viz. that of initial pressures of comparatively low degree, commencing at the works, and diminishing as the mains pass through the district and the gas is drawn off for consumption.

That this is, under existing conditions, an inadequate and wasteful system, goes without saying. Inadequate, because it cannot accomplish the desired effect of maintaining a uniform pressure throughout the district; and wasteful, because it means the sinking of an unnecessary amount of capital in a multiplicity of large leading mains. Electricians soon discovered that low-pressure supply entails too heavy a capital expenditure; and, although gas mains are less costly than electric mains, there is no reason why we should adhere to a system the defects of which are so apparent, when the same remedy is just as easy to our hands as to those engaged in electric lighting. The fear of high pressure in conducting mains is a "bogie" the dangers of which are greatly exaggerated. We know from experience that mains of considerable size, if well laid in the first instance, do not give rise to leakage of any importance. Why, then, should we not have high-pressure trunk mains delivering gas into the distributing mains through governors, acting as transformers, situated in convenient positions in the district, in or near the centres of consumption? By adopting such a system, we should dispense with the constant duplication or enlargement of leading mains; and the problem of increasing the delivery of gas would resolve itself into putting additional governors in fresh positions and connecting them to the district mains.

Too little is known about the proper relationship of the

mains to the consumption. Although there are well-defined formulæ for the calculation of the capacity of main pipes as regards the delivery of gas, yet the size and number of main pipes used for the supply of a definite hourly quantity is subject to an almost infinite variety; and the divergencies between the main piping in one town and another are most unaccountable. There are, of course, differences in the conditions of supply in different towns; but it is difficult to believe that these differences are so great as to account for such divergencies in the length of piping and the consumption of gas as are to be found among the returns of gas undertakings.

Then there is the question of unaccounted-for gas. Out of a total annual make of gas in the United Kingdom amounting to 127,000 million cubic feet, 10,000 million are unaccounted for; representing a million tons of coal annually apparently wasted so far as any return for it is concerned. This is equal to 8 per cent. of the gas made. Although part of this is, no doubt, due to shrinkage through reduction of temperature, there still remains a serious deficiency which cannot thus be accounted for. There does not appear to be much difference between gas companies and municipal undertakings in respect of unaccounted-for gas. There are, however, many undertakings of both kinds which fail to come up to the usually accepted standards in regard to sales of gas per ton of coal. Among the companies, 52 per cent. of the total number included in the last Parliamentary Returns sell under 9000 cubic feet to the ton, and 19 per cent. sell under 8000 cubic feet per ton. Of local authorities, 54 per cent. sell less than 9000, and 16 per cent. less than 8000 cubic feet per ton. Amongst the small undertakings, both of companies and local authorities, are to be found the most extraordinary sinners in this respect; but there are not wanting undertakings of magnitude whose returns might be improved with marked advantage to themselves. There is surely proof here that the distributory plant does not receive that attention which it deserves. Whether the discrepancy between the gas made and the gas sold is to be charged to leaky mains, decayed service-pipes, or incorrect meters, there are defects somewhere which might and ought to be remedied.

Whilst upon the subject of the Returns as to gas undertakings, I wish to call your attention to the fact that the

number of authorised undertakings owned by companies has in ten years increased by 14 per cent., and those in the hands of local authorities have increased 28 per cent. But the capital employed by the companies has increased 35 per cent.; whilst that of gas-works owned by local authorities has increased only 27 per cent. In 1886, the capital employed by gas companies amounted to 6*l.* 6*s.* 9*d.* per ton of coal carbonised; in 1896, it amounted to 6*l.* 9*s.* 2*d.* per ton—an increase of 2*s.* 5*d.* The capital employed by local authorities amounted in 1886 to 5*l.* 12*s.* 1*d.* per ton of coal; in 1896, it stood at 4*l.* 8*s.* 10*d.* per ton—a reduction of 1*l.* 3*s.* 3*d.* per ton having taken place. These figures reveal the great advantage local authorities possess in the redemption of their capital by means of a sinking fund—an advantage which it has been suggested should be given to gas companies also. Surely, however, apart from this, it might be expected that the companies would, in the course of a decade, show some reduction in capital account per ton of coal carbonised, due to their growth of business; for, as the magnitude of the operations increases, the cost of the additional plant diminishes, and the dead-weight of capital due to preliminary expenses becomes spread over a larger total. I make these remarks in the full knowledge that many companies do keep this desired end in view, and follow it successfully.

There is another influence at work, the effect of which is all in favour of an ultimate reduction in the proportionate capital employed, and that is the gradual levelling-up of the day consumption, and the diminution of the difference between the summer and winter consumption caused by the employment of gas for other than lighting purposes. The rapidly extended use of cooking stoves encouraged by the hire system and by the slot meter, with its accompanying free boiling-stove, is continually increasing the proportionate consumption of gas during daylight hours. The use of gas as a motive power further assists in accomplishing this result. During ten years the day consumption in Manchester has risen from 20 to nearly 30 per cent. of the total; and I do not doubt that there are many undertakings in which a more marked result has followed the endeavours made to develop the day consumption. As for the winter consumption as compared with that of the summer months, we find in Manchester that the rate of increase is greater during the latter than during the former, and that the extension of electric lighting has tended to keep down an

unusually large demand on foggy days in winter, while not perceptibly affecting the annual consumption as a whole.

In the matter of utilising the energy in coal gas, we are yet only in the elementary stage; but great changes are impending. Hitherto a mere fraction of this energy has been converted into light; but the incandescent gas-burner and the Welsbach mantle have opened the way for the conversion of a much larger proportion of the store of heat-energy contained in gas into illuminating effect. The improved burner now being introduced by the Welsbach Company will, it is believed, greatly enhance the value of this method of lighting. The importance of these developments can hardly be over-estimated. While the utilisation of the energy of the electric current as applied for producing light has apparently little margin left for improvement, there remains an almost boundless surplus energy in gas. Its economical conversion into light must be our special study in the immediate future. When gas lighting becomes independent of the direct illuminating power of the gas, we shall be able to supply a gas which, while satisfying all requirements for illumination, will be cheap enough, and yet possess sufficient energy for all the various purposes, industrial and domestic, for which gas is so eminently convenient. Under such improved conditions, public lighting by gas will continue to be the cheapest and most effective system; and as the consumption of gas per unit of light evolved diminishes, and the consumption for other purposes increases, the present strain on the resources of the gas-works in our large towns, due to fogs, added to the normal winter consumption, will be relieved, and a more regular rate of consumption be attained.

One source of the revenue of gas undertakings has unfortunately been of late a diminishing quantity. I refer to the sale of our residual products. Tar and ammonia do not at present, and probably never will again, command the prices they once did. So far as tar is concerned, gas tar does not now contain so large a proportion of the more volatile hydrocarbons as formerly; but seeing that the market value of benzol has become so reduced, it does not appear that the lesser quantity of this constituent can seriously affect the returns realised for tar. In the manufacture of sulphate of ammonia, the margin of profit has been so low during the last few years, that only with plant of the most economical character, in which mechanical appliances have been substituted for hand labour throughout, could

gas undertakings show any advantage in working up their ammoniacal liquor. There are now signs of a permanent improvement in the price obtainable for this product; and in the case of those undertakings which still sell their tar and liquor the adoption of a sliding-scale of prices has at least ensured them a fair share of the profits to be realised. The endeavours which have been made to add to the returns from the by-products of gas manufacture by the abstraction of the cyanogen in the gas have not met with all the success anticipated, owing to the fluctuation and uncertainty in the value of cyanides. Coke still remains a valuable source of revenue; and the increased yield of coke disposable for sale has done much to counteract the loss of income from the other residuals. Much may be done to create and maintain a good demand for coke at fair prices by studying the requirements of the district in which it is desired to sell it, and providing the necessary machinery for cleaning, breaking, and separating the coke and breeze into such sizes as are suitable for the purposes for which the former is required.

Gentlemen, I think you will agree with me that the foregoing review of the present position of the gas-manufacturing industry, imperfect though it is in many respects, suffices to show that, while changes do, and inevitably must, occur in the conditions under which we have to carry on the business, there is nothing in these changes to alarm us, nor are they likely to be so sudden as to upset our calculations or revolutionise our methods. Nevertheless it behoves us to be on the alert to appropriate all such modifications as the change of circumstances may give rise to; and, if we cannot ourselves become the initiators of them, to grasp and appreciate their value, and be the first to utilise them to our own advantage. I rejoice to feel that to this Institution, and to kindred associations in this and other countries, assisted by the technical press, belongs the credit of keeping alive the interest in, and bringing about the adoption of, all such improvements in the working and administration of the numerous undertakings identified with the supply of gas—an industry in which, in Great Britain alone, more than 70 millions sterling are invested; and that the employment of this immense capital continues, under the technical management which we here to-day largely represent, to be uniformly productive of good financial results.

SECOND AND FINAL REPORT OF THE COMMITTEE ON THE PROPOSED STANDARD OF LIGHT AND TEMPERATURE OF GAS MEASUREMENT.

YOUR Committee report that at their first meeting, held on the 11th June, 1896, the following were appointed a Sub-Committee to consider the question of temperature of gas measurement, viz. Messrs. A. Colson, C. Hunt, F. Livesey and R. O. Paterson.

The report of this Sub-Committee, giving the results of observations conducted by each of its members separately, and the conclusions to be drawn from them, is herewith submitted. With these conclusions your Committee are in agreement.

Your Committee deeply regret to have to record the loss by death of one of their Members, Mr. John Methven, whose assistance in the first part of their investigations proved, from his special and intimate knowledge of photometry, of the highest possible value.

CHAS. HUNT, *Acting Chairman.*
CHARLES C. CARPENTER.
ALFRED COLSON.
FRANK LIVESEY.
G. C. TREWBY.
R. O. PATERSON.

May 24th, 1898.

REPORT OF THE SUB-COMMITTEE.

The Sub-Committee submit particulars of observations of temperature made in their respective districts, and extending over a considerable period of time. These have been plotted out in diagrammatic form, so as to bring more clearly to view the point of the investigations. They prove that the tempera-

ture of the gas at the consumers' meters follows that of the air; although it is not always subject to the same variations as the latter, owing probably to the more or less sheltered positions of the meters. Thus, while extreme variations of 27° and 29° Fahr. occur in the air temperature, those of the gas temperature during the same period ranged from 28° down to about 11° Fahr.

It will be seen from the observations that the gas temperature only approximates to 60° during the four or five summer months. Throughout the remainder of the year, and especially during the period of heaviest consumption, it falls considerably below 60°, the lowest monthly average recorded being 35°, which is a difference of 25°, and would represent a contraction of volume of more than five per cent. The customary correction of the make to 60° Fahr. is therefore of little use for the purpose of comparing the gas sold with the gas made, and only tends to increase fictitiously the quantity of so-called leakage or unaccounted-for gas.

In order to determine with some degree of accuracy the actual loss due to leakage, imperfect registration at the consumers' meters, or other causes, this source of error requires to be eliminated. For this purpose it seems to be necessary to vary the corrections say weekly, following the ascertained atmospheric temperature, but adding thereto or deducting therefrom a few degrees to compensate for any higher or lower observed average temperature at the consumers' meters. This compensation does not, however, seem to be invariably required, since the records show in two instances a close agreement between the temperatures of air and gas.

ALFRED COLSON.
CHAS. HUNT.
FRANK LIVESEY.
R. O. PATERSON.

May 2nd, 1898.

LEICESTER

AYLESTONE

Distance from Works and Number.	Average Atmospheric Temperature at Works.	At Works. 1		1¼ Mile. 2		¾ Mile. 3		¾ Mile. 4		¾ Mile. 5	
Description of Meter.		400 Light Wet.		300 Light Wet.		150 Light Wet.		150 Light Wet.		500 Light Wet.	
		Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.
1896.											
November . .	39	56	42·57	42	46·00	42	43·66	42	51·80	42	49·97
December . .	37	56	41·26	36	48·13	36	42·44	38	50·73	38	49·57
1897.											
January . .	34	46	39·69	34	47·64	34	43·00	34	48·88	34	49·97
February . .	43	56	42·71	38	45·31	38	43·97	36	49·77	36	52·66
March . . .	45	62	45·87	50	48·64	50	48·02	48	50·56	48	53·25
April . . .	46	60	46·21	44	51·15	44	47·52	37	51·37	37	54·35
May . . .	52	52	51·46	40	53·07	32	53·40	33	53·06	32	54·57
June . . .	61	54	59·59	32	60·46	29	61·17	16	59·50	16	62·75
July . . .	63	52	63·44	39	63·38	37	64·86	31	62·16	27	64·36
August . . .	63	62	64·03	38	62·97	38	65·50	27	67·85	28	63·78
September . .	53	60	56·26	44	56·86	44	58·72	39	59·53	39	57·46
October . .	49	62	51·77	24	53·91	24	54·58	36	56·66	36	58·94
November . .	44	6	48·16	4	53·00	4	50·50	4	54·00	4	53·50

CORPORATION.

ROAD WORKS.

3¾ Miles. 6		1¾ Mile. 7		1¼ Mile. 8		1¼ Mile. 9		2¾ Miles. 10		1 Mile. 11		¼ Mile. 12	
50 Light Wet.		150 Light Wet.		150 Light Wet.		5 Light Wet.		3 Light Wet.		3 Light Wet.		3 Light Wet.	
Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.
42	52·61	42	52·57	52	54·75	58	43·84	58	44·27	58	41·44	58	47·32
33	50·66	37	51·89	62	53·50	62	41·72	62	43·29	62	41·74	60	47·61
34	47·55	34	50·54	50	53·94	50	39·40	38	41·21	50	38·44	50	45·72
38	52·13	36	53·08	56	55·25	56	41·96	56	45·32	56	45·17	56	45·00
50	53·62	50	54·96	62	55·46	62	42·87	62	48·43	62	46·06	62	51·48
34	53·14	34	55·02	60	54·83	60	43·46	60	50·90	60	47·46	60	52·36
34	55·85	33	48·69	52	59·34	54	47·72	54	58·12	54	52·72	54	55·92
25	63·44	26	65·23	53	61·86	60	54·06	58	63·29	60	61·56	52	62·46
28	65·71	26	67·30	52	64·11	30	57·00	56	68·19	56	65·57	56	66·00
27	65·62	26	64·92	58	63·82	60	58·06	56	65·75	54	65·92	59	64·30
43	60·04	43	60·55	56	60·32	60	54·30	32	60·37	40	56·40	45	60·37
28	59·92	10	56·60	40	58·15	62	52·43	60	53·86	62	52·33	58	55·96
4	53·00	no	record	6	55·00	4	50·00	4	55·50	4	49·00	6	54·00

CITY OF BIRMINGHAM.—WINDSOR STREET WORKS.

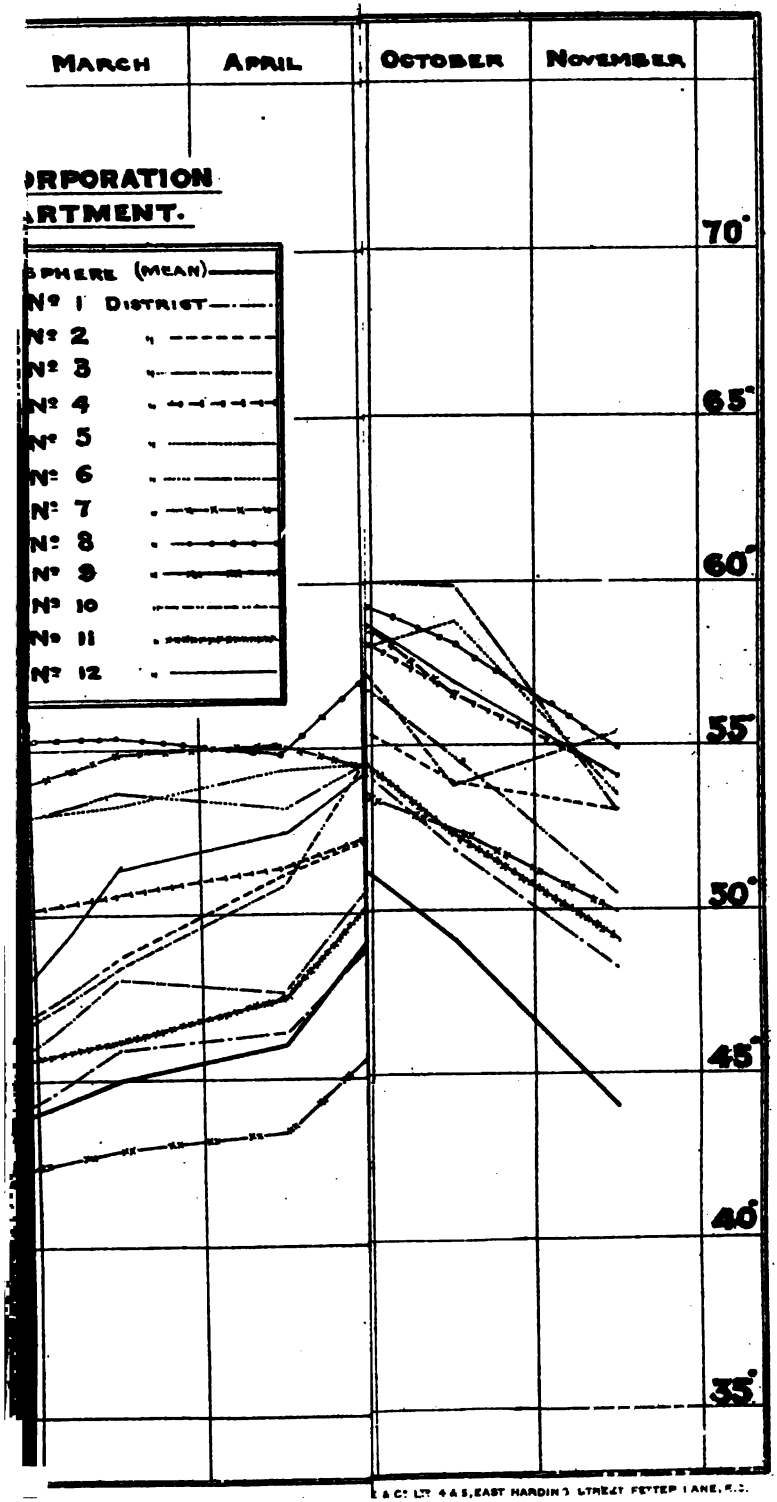
Distance from Works and Number.	Average Atmospheric Temperature in Birmingham.	About 2 Miles. 1		About 7 Miles. 2		About ¾ Mile. 3		About ¾ Mile. 4		About 1¼ Mile. 5		About 1¼ Mile. 6		About ¾ Mile. 7		About 1¼ Mile. 8		About 1¼ Mile. 9	
Description of Meter.		20 Light Wet.		5 Light Dry.		5 Light Wet.		5 Light Wet.		5 Light Wet.		5 Light Wet.		3 Light Wet.		5 Light Wet.		3 Light Wet.	
		Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.
1896.																			
November . .	37·7	48	44·8	25	47·5	22	43·5	25	43·2	24	44·1	23	45·3	15	45·4	26	43·6	25	43·4
December . . .	37·7	59	44·0	29	44·0	30	42·0	31	42·1	26	41·4	22	43·0	9	44·2	30	42·4	31	43·0
1897.																			
January . . .	34·0	62	40·3	23	41·5	31	39·0	30	40·2	28	35·7	no	record	24	40·6	26	40·6	31	39·2
February . . .	42·0	56	43·4	26	45·0	27	43·3	28	46·0	22	40·5	"	"	28	42·5	28	42·4	28	42·7
March	43·4	57	44·4	31	47·2	30	44·7	12	44·5	24	41·4	"	"	31	44·5	31	44·5	31	44·0
April	43·7	49	45·1	30	46·6	30	45·6	no	record	29	45·4	28	46·0	27	45·8	27	45·0	30	43·5
May	49·9	38	47·9	12	49·3	27	49·2	"	"	26	50·7	31	50·5	31	49·2	31	48·4	31	46·4
June	58·7	no	record	no	record	29	54·3	"	"	24	55·2	30	57·1	30	55·0	24	56·2	no	record
July	61·5	35	56·7	"	"	31	59·2	"	"	24	61·3	30	60·2	30	58·3	28	59·0	"	"
August . . .	60·5	14	58·6	"	"	25	60·3	"	"	28	63·6	15	62·8	18	60·5	31	60·8	"	"
September . .	52·9	28	54·1	"	"	no	record	"	"	24	60·0	30	57·0	30	56·6	30	55·9	"	"
October	49·9	19	52·0	"	"	"	"	"	"	26	54·5	31	53·0	31	53·4	31	51·3	"	"
November, to 15th	44·8	11	50·4	"	"	"	"	"	"	13	50·9	11	49·8	11	50·6	11	48·5	"	"

SOUTH METROPOLITAN GAS COMPANY.—OLD KENT ROAD.

Distance from Works and Number.	Average Atmospheric Temperature at Works.	About ¼ Mile. 1		About 1¼ Mile. 2		About ¾ Mile. 3		About 1¼ Mile. 4		About 3¼ Miles. 5	
Description of Meter.		5 Light Dry.		5 Light Wet.		5 Light Dry.		5 Light Dry.		10 Light Dry.	
		Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.
1896.											
August . . .	59	no	record	20	62·2	no	record	18	66·2	11	61·4
September . .	56	42	60·9	58	61·0	57	60·3	60	64·2	60	61·1
October . . .	47	58	51·7	65	53·5	65	51·6	64	56·3	65	53·8
November . .	41	70	46·3	90	49·3	90	47·0	90	51·5	80	47·8
December . .	40	75	45·4	92	48·8	93	45·6	93	49·4	91	46·7
1897.											
January . . .	36	78	42·0	93	44·8	93	41·7	93	46·2	93	42·8
February . . .	40	74	45·6	78	50·8	84	47·5	84	51·6	84	47·3
March . . .	44	no	record	10	55·6	93	48·9	93	54·2	93	49·7
April	46	"	"	60	53·3	90	49·4	89	56·0	90	51·2
May	47	"	"	60	58·0	92	54·3	83	60·1	93	55·8
June	60	"	"	49	65·5	90	62·3	67	67·4	89	62·0
July	63	"	"	62	68·1	93	65·3	78	71·2	93	65·9
August . . .	62	"	"	62	68·1	24	68·9	79	70·9	52	65·3
September . .	55	"	"	18	62·2	no	record	38	62·2	28	61·5

CHELTENHAM GAS-LIGHT AND COKE COMPANY.

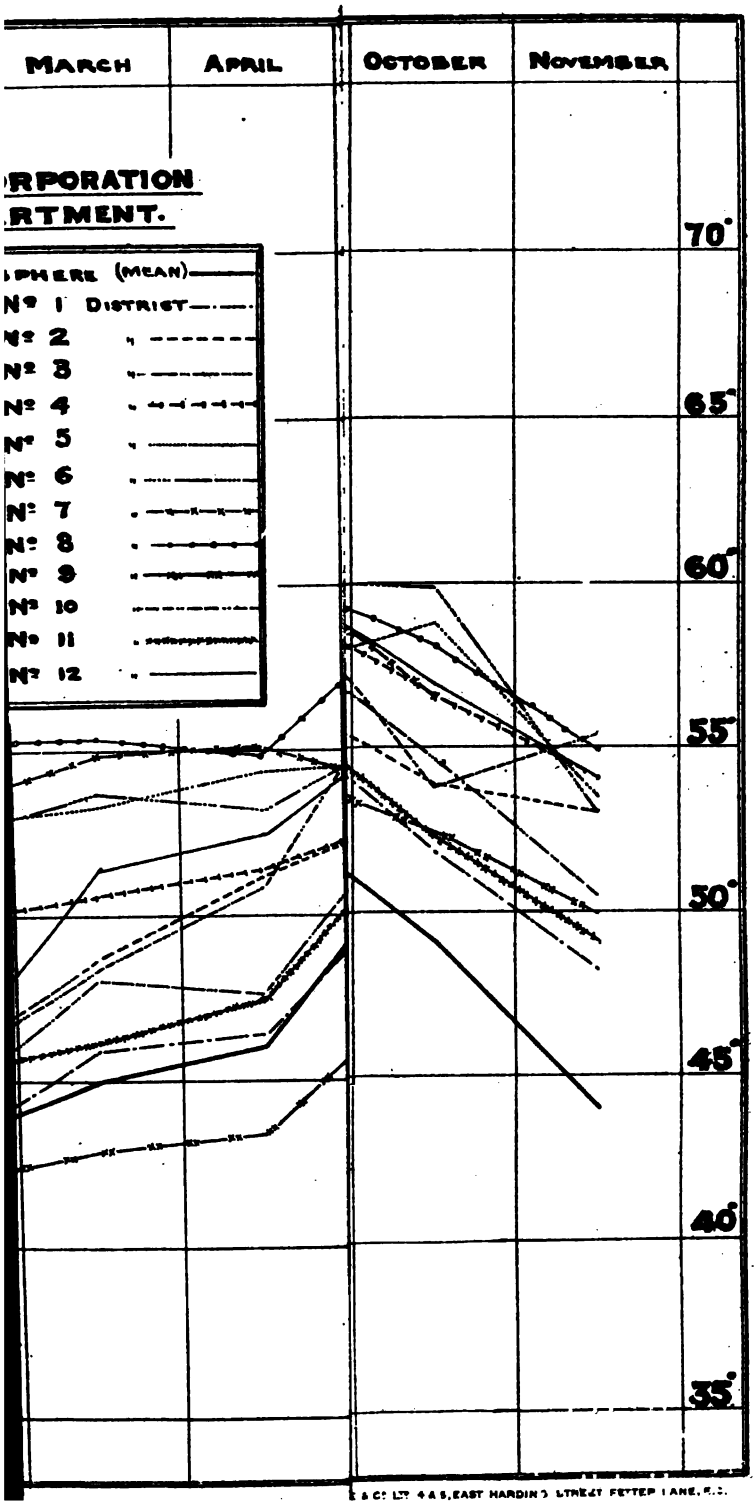
Distance from Works and Number.	Average Atmospheric Temperature in Cheltenham.	About ¼ Mile. 1		About ½ Mile. 2		About 1¼ Mile. 3		About 1¼ Mile. 4		About 2 Miles. 5	
Description of Meter.		80 Light Dry Meter.		5 Light Dry Meter.		5 Light Dry Meter.		10 Light Dry Meter.		10 Light Dry Meter.	
		Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.
1896. December . .	38·5	61	44·7	41	42·7	110	46·8	58	44·4	44	43·4
1897. January . .	35·0	46	41·8	29	40·5	101	41·1	53	42·5	57	39·0
February . .	43·8	40	46·4	26	44·4	79	44·4	31	46·0	45	42·7
March . . .	45·3	44	48·0	30	45·3	97	45·3	25	47·2	61	43·2
April . . .	46·2	35	48·9	27	46·9	92	47·0	18	47·3	56	48·1
May . . .	50·7	34	53·7	25	50·4	62	51·7	9	52·7	53	49·4
June . . .	60·8	36	60·2	26	58·6	60	57·8	15	57·8	27	59·1
July . . .	63·3	36	64·5	27	61·7	60	63·3	no	record	31	63·2
August . . .	61·2	36	64·4	28	65·4	58	64·1	"	"	30	62·2
September . .	53·7	34	57·1	22	58·8	58	59·5	"	"	60	55·3
October . .	50·1	38	53·1	24	50·3	58	53·0	"	"	62	52·1
November . .	45·3	42	49·3	28	47·9	61	48·0	25	50·0	43	47·2
December . .	41·6	38	45·4	28	43·8	60	46·3	50	46·0	31	46·9
1898. January . .	43·0	36	48·0	30	45·9	62	43·4	36	48·4	31	47·8



E & Co LTD 4 & 5, EAST HARDING STREET FETTER LANE, E.C.

CHELTENHAM GAS-LIGHT AND COKE COMPANY.

Distance from Works and Number.	Average Atmospheric Temperature in Cheltenham.	About ¼ Mile. 1		About ½ Mile. 2		About 1¼ Mile. 3		About 1¾ Mile. 4		About 2 Miles. 5	
Description of Meter.		80 Light Dry Meter.		5 Light Dry Meter.		5 Light Dry Meter.		10 Light Dry Meter.		10 Light Dry Meter.	
		Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.	Number of Observations.	Average Temperature at Inlet.
1896. December . .	38·5	61	44·7	41	42·7	110	46·8	58	44·4	44	43·4
1897. January . .	35·0	46	41·8	29	40·5	101	41·1	53	42·5	57	39·0
February . .	43·8	40	46·4	26	44·4	79	44·4	31	46·0	45	42·7
March . . .	45·3	44	48·0	30	45·3	97	45·3	25	47·2	61	43·2
April . . .	46·2	35	48·9	27	46·9	92	47·0	18	47·3	56	48·1
May . . .	50·7	34	53·7	25	50·4	62	51·7	9	52·7	53	49·4
June . . .	60·8	36	60·2	26	58·6	60	57·8	15	57·8	27	59·1
July . . .	63·3	36	64·5	27	61·7	60	63·3	no	record	31	63·2
August . . .	61·2	36	64·4	28	65·4	58	64·1	"	"	30	62·2
September . .	53·7	34	57·1	22	58·8	58	59·5	"	"	60	55·3
October . .	50·1	38	53·1	24	50·3	58	53·0	"	"	62	52·1
November . .	45·3	42	49·3	28	47·9	61	48·0	25	50·0	43	47·2
December . .	41·6	38	45·4	28	43·8	60	46·3	50	46·0	31	46·9
1898. January . .	43·0	36	48·0	30	45·9	62	43·4	36	48·4	31	47·8



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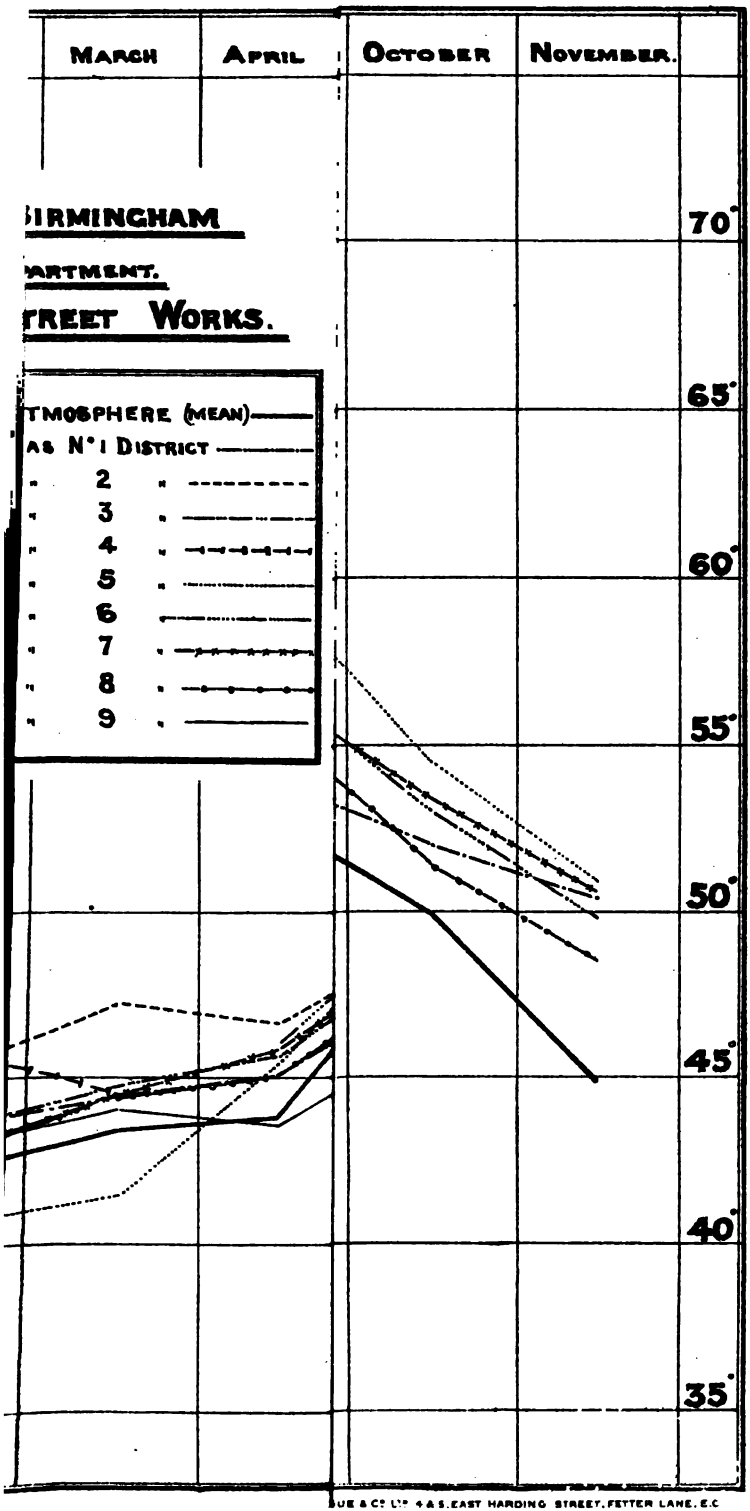

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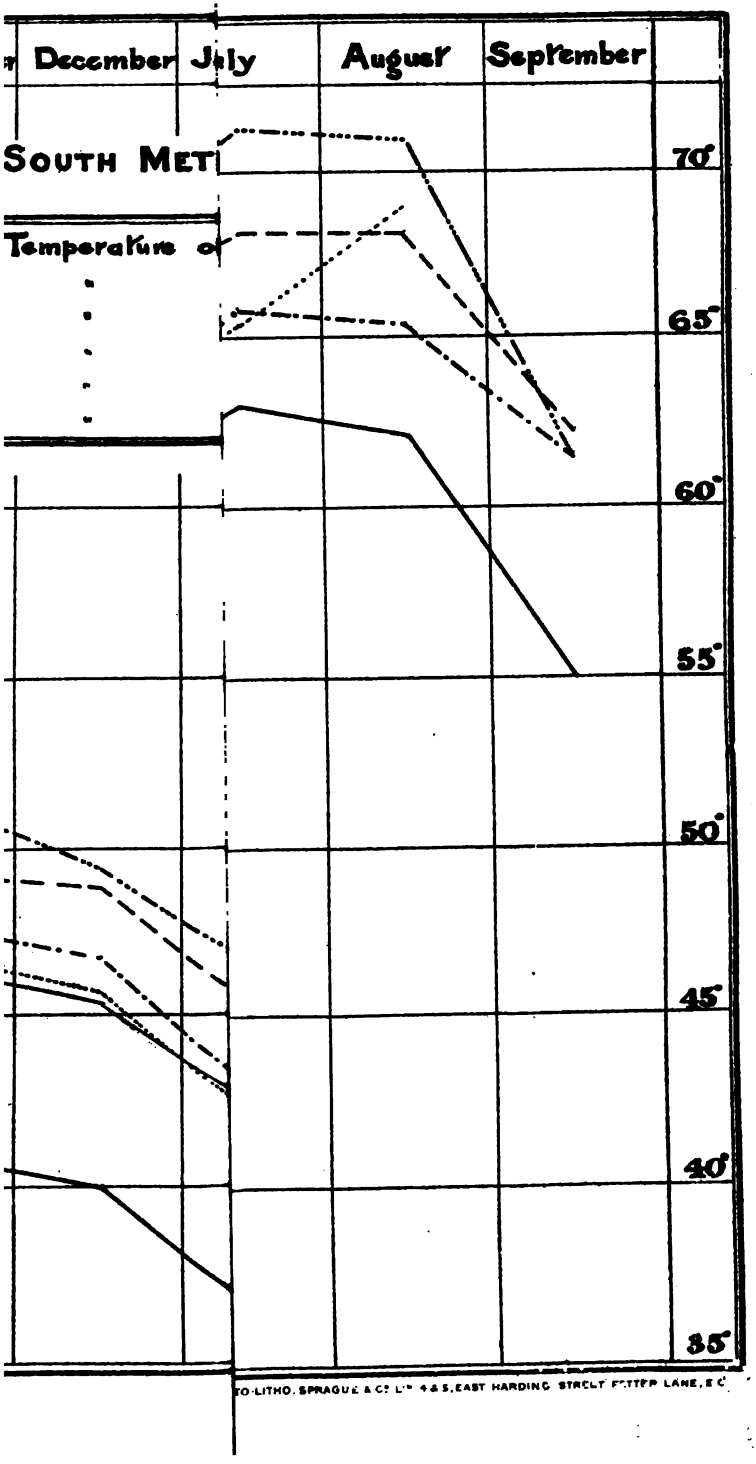
December
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August
September
SOUTH MET
Temperature of
70°
65°
60°
55°
50°
45°
40°
35°
TO-LITHO. SPRAGUE & Co. Ltd. 4 & 5, EAST HARDING STREET FETTER LANE, E.C.

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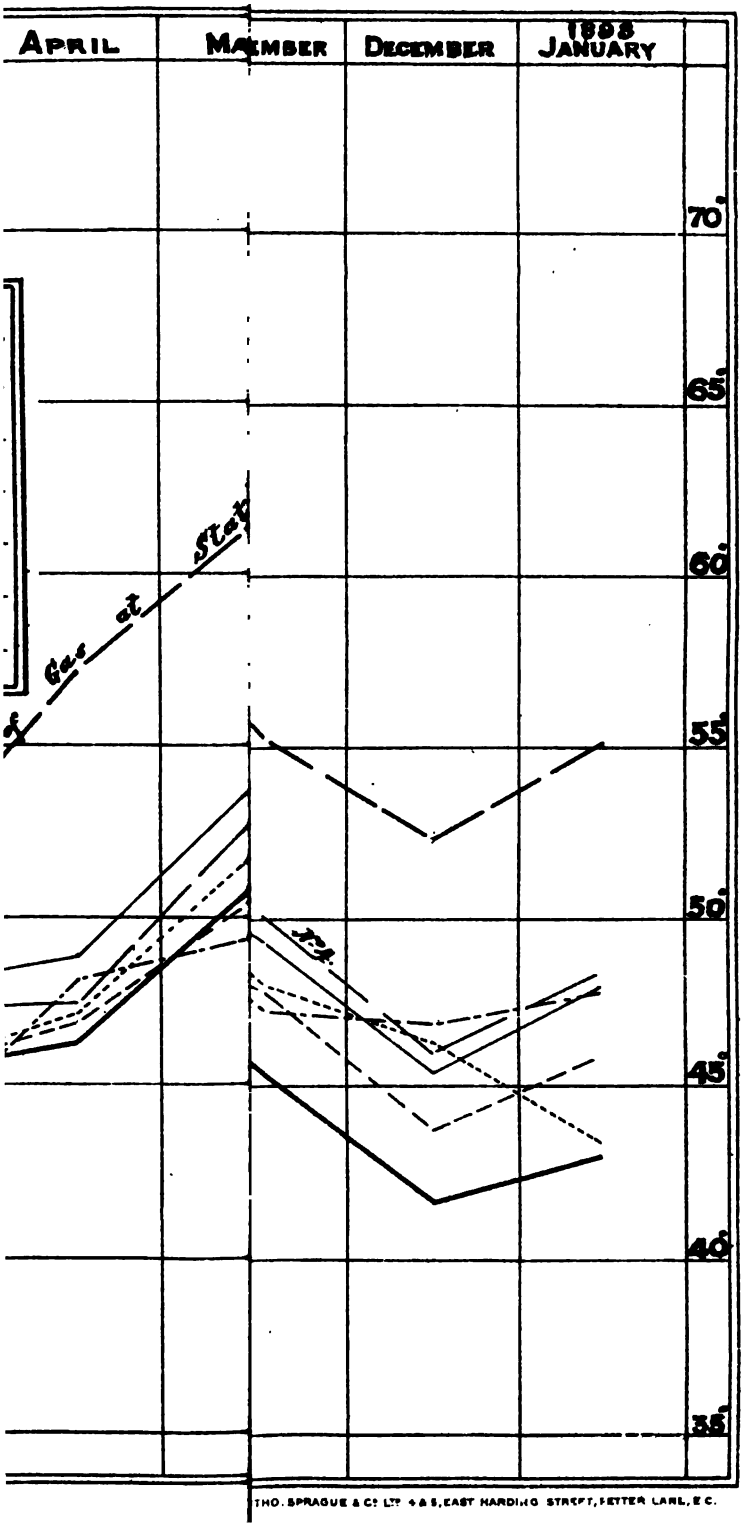

THO. SPRAGUE & Co. LTD. 4 & 5, EAST HARDING STREET, FETTER LANE, E.C.

DISCUSSION.

Mr. HUNT (Birmingham): With regard to the first report, I should like to emphasise two facts. The first is that, in the whole of the experiments made with the Dibdin burners the method of substitution was employed, and thus, any source of error which might arise from reflection or imperfect eye-sight was entirely eliminated. In the second place, two principal difficulties were met with in the experiments—one, that the burners are not interchangeable—that is to say, hardly any two burners that were tested were found to be alike, and the other that the chimney is likely to be a principal source of error. The first objection may be due partly to imperfect manufacture, and partly to the chimney; the second, of course, is attributable to the chimney alone. But, both these defects having now been acknowledged and in the most practical way by the introduction of a new chimneyless burner, it is probably hardly worth while to discuss them; nor is it desirable to anticipate anything which might more appropriately be said on Mr. Harcourt's paper, to which we all look forward with much interest. I will, therefore, pass on to the second report, relating to the temperature at which the gas is measured. This, it will be recollected, arose out of a paper read by Mr. George Livesey two years ago, in which he impugned the desirability of the usual practice of correcting to a temperature of 60° Fahr. the volume of gas as measured at the works. At that time I was one of those who doubted the desirability of any change, and I was justified in this doubt by the series of observations made in Birmingham with regard to one meter only at one particular part of the district. The temperature at this meter seemed to agree fairly well with that of 60°, to which the measurement at the works is corrected. The results of the experiments made by the Committee, however, show clearly the undesirability of founding any opinion on a single set of observations; for, taking the average of them, it is proved that the temperature of the gas follows that of the air—not exactly, because no doubt the position of the consumers' meters varies. There is, however, a distinct relation between the temperature at which the gas is measured and the atmospheric temperature. In my own case, the difference between the correction to 60° and the volume which would

have been recorded had the temperature at the consumers' meters been taken, amounted to nearly 2½ per cent.—that is to say, the unaccounted-for gas, instead of being recorded at something less than 6 per cent., would only have been about 3½ per cent., this being the actual loss due to leakage and waste of all kinds. This seems to prove the great importance of the matter, which is in some cases doubtless in the hands of the gas manager himself. It depends very much upon the relative position of the station meter and purifiers whether or not the temperature as measured approximates with that of the air. I suggested this in the discussion which took place two years ago; but was at once met by the objection that, especially in large works, it is exceedingly difficult to obtain anything like sufficient cooling between the purifiers and the station meter to ensure a temperature approximating to that of the air. I quite admit the force of this objection; and the suggestion in the report is that, instead of the correction being made to 60°, it should be made weekly according to the average observed temperature of the atmosphere. This would not be an exact record of the alteration due to the temperature, but it would be near enough for the purpose of ascertaining the actual loss due to leakage, imperfect registration and other causes. An idea seems to prevail that, if the temperature be taken when the consumption is least, it will not correctly record the actual temperature at which the gas is measured. Now, one of the sets of observations made in Birmingham was made by myself at my own house. For some considerable time I took the temperature during the morning, when the consumption was least, and also at night, when it was supposed to be greatest; and I found little or no difference between the two. Any difference there might occasionally have been was traceable to some change having taken place in the atmospheric temperature. After a few months, therefore, I gave up making two observations daily, and only took the temperature in the evening, during the period of greatest consumption.

I do not know whether it may be thought desirable to take any further collective action in this matter; but if so, it should probably be in the form of a recommendation that for the purpose of ascertaining the actual loss of gas through leakage and other causes, the usual correction to 60° should give place to a correction to the average temperature of the atmosphere.

Mr. GEORGE LIVESEY: I suggest that it should be a little above atmospheric temperature.

Mr. HUNT: Perhaps it should be a few degrees higher, to correct any difference there may be between the temperature at the consumers' meters and that of the air. This, however, is not in every case necessary.

Mr. R. O. PATERSON (Cheltenham): I think Mr. Hunt has very fairly laid before the meeting the points which have arisen upon this second report of the Committee, but I should just like to utter a word of caution. I am not quite sure that we are prepared to go to the extent of making a recommendation of such a definite character, because we might get such a number of different standards all over the country that it would be very difficult indeed to make comparisons in the future. The observations which have been made have shown very clearly that the correction to 60° is a decided method of obtaining a high leakage amount; the measurement of the gas at the consumers' meters is undoubtedly found to be considerably lower than 60°. On the other hand, many of us have never corrected the gas measured at the station meter to 60°. In my own case I have never done so, because I have always had the idea that the average of the twelve months would bring me out nearly level, and I prefer leaving it alone. I made a diagram of these temperatures, and I found that supposing I had corrected every month I should have had less than a-half per cent. difference in the volume of gas; that is to say, the gas measured at the station meter without correction when corrected to 60° would simply have given an increased volume of ½ per cent.; so that there is not much in the correction to 60°. If we are going to propose to correct to 55° or 50° I am afraid that the comparisons over the country will be rather confused, and I myself am not prepared to go quite so far as that. Another point which arose in the course of my experiments in this matter, was that some care must be exercised in deciding at what point the temperature of the gas is measured at the station meter. I found in all my experiments that the temperature at the inlet of the station meter is considerably different from the temperature at the outlet. The water which is constantly trickling into the station meter is at the usual temperature, but in the overhead tank it is invariably below 60°. I have taken the mean of those two temperatures, but I am not quite sure

engaged the attention of the chairman and engineers of the South Metropolitan Company, more particularly with reference to the large increase in the demand for gas which the past two or three years have seen. There appears to be no doubt whatever, that the present system of distributing gas at a pressure which is sufficient for the consumers is an uneconomical one, and that a very large increase in the carrying capacity of the mains can be brought about by placing them under a high pressure and isolating the early portions of the mains from the consumers' meters. A plant for the purpose has been in operation at one of the South Metropolitan stations throughout the whole of last winter. We used a Sturtevant blower in preference to the positive exhauster which Mr. Stevenson suggested at Sheffield. There are one or two advantages about the Sturtevant type of blower or exhauster. I think the most important point is that the safety by-pass is not rendered necessary, because with the blower, it not being a positive machine, there is a full gas way, whether the machine is revolving, or whether it is not. An ordinary exhauster, as you know, is a positive instrument, and unless it is kept in motion it acts as a very efficient stop to the progress of any gas, but with a blower of the kind that the South Metropolitan have been using, it does not matter whether the blower is running or not. If it is not running, you get the full volume of gas through it. It has been our practice to use it during the hours of lighting. The first operation is to open the inlet and outlet of the blower, and the gas then goes through in the usual way. As the time comes for putting on the pressure the blower is started, and in two or three minutes the full speed is reached, supplying gas at whatever pressure may be desired. In one case we use it to draw gas at a pressure of something like 3 inches at the inlet, and that is increased at the outlet to as much as 7 or 8 inches. The quantity dealt with by one machine is approximately 300,000 cubic feet an hour. To do that a fan is used which is driven by a 6-horse engine and boiler, so that, if you compare it with an exhauster of a power to deal with anything like that quantity, it will be seen that there is an enormous advantage in using a blower of the type suggested in preference to the positive exhauster. I may further say that arrangements have been made to largely extend that system of distribution, and plans are now being considered for using blowers

capable of dealing with 1,500,000 cubic feet per hour. I think it will be impossible to deal economically with that quantity in any other way. With reference to the objection to the use of high-pressure gas, the South Metropolitan have been using high-pressure mains for the last ten years, having had two during part of that time, and part of the time three. The pressure in those mains runs up to 12 or 13 inches, and during the ten years I have only known of one leakage.

Mr. LIVESEY: They are not distributing mains.

Mr. CARPENTER: They are not. I am speaking from the point of view of safety. Each of the mains is about a mile long, and they have been in operation for the last ten years. Only once has there been any serious leakage, and that was due to a large sewer made under a very busy part of the roadway through which the mains ran, so that I think there is practically no danger of the leakage of gas. I do not think there is any extra danger in distributing gas under 10 or 12 inches pressure.

Mr. GEORGE LIVESEY: I have very little to say after what Mr. Carpenter has told the meeting. The difficulty arose in this way—the question was constantly coming before us of laying larger mains in order to supply the extremities of the district. We have a number of large mains leading out of the different distributing stations; and some are independent mains. The one Mr. Carpenter spoke of is an independent main leading to Clapham Junction—it was laid for the sole purpose of helping the supply at that place, which is rather a low-lying district with a large consumption. The size of the main is—

Mr. CARPENTER: 24 inches at the start and 18 inches at the end.

Mr. G. LIVESEY: This main, by cutting off one or two connections, was made independent, and gas being put into it at a high pressure and supply, it went into the district where it was wanted. Of course, a 6-inch pressure would never do where there were wet meters, because it would blow the water out. But by working 6 inches at the start we got to something like 3 inches at the end of two miles; and then it went into the distributing mains. It was more effective than we anticipated. It backed up the other governors, and got us out of the difficulty, and gave just the pressure that was wanted. The idea at first was to have an ordinary exhauster; but that

seemed so cumbrous that one day passing the Sturtevant blower office in Queen Victoria Street, I called in and looked at it. The arrangements were entrusted to Mr. Carpenter, and within a fortnight the necessary appliances were obtained and the blower was put into operation. This shows how easily and quickly it was done. My first idea was to have a by-pass, valves, &c., but Mr. Carpenter said no by-pass was necessary, as it is a free and open blower, and if stopped the gas will flow through it without any difficulty just the same as an ordinary main. Our intention is to make use of this system for supplying pressure throughout our districts through independent mains. We happen to have certain independent mains which will be used for conveying gas at high pressure to the extremity of the district. Since the introduction of large holders we have been placed in this difficulty, that when the lower lifts landed, the upper lifts did not give pressure enough to supply the district. Taking our own storage at something like 45 million cubic feet, there is 10 to 15 million which is of little use to us. By putting a Sturtevant blower on the main leading to the governors we can put what pressure we like on the governors and thus convert a low pressure into a pressure sufficient to supply the district. I suggested that Mr. Carpenter should read a paper on the subject, but it was thought better to wait until next winter, when we shall have more experience on the matter.

Mr. G. C. Trewby: I think I might say a few words on this question, as practically the whole of our Beckton gas has to be pumped up to London. When the works were first laid out they were laid with one main of 48 inches; and all the pressure we could give was a gasholder pressure of 6 inches. It was soon found this was not sufficient in London; and we had exhausters put on—ordinary Beale exhausters, and the gas was pumped up. We have now a second 48-inch main; and every foot of gas sent away from Beckton is pumped, because the gasholder pressure merely would not be of the slightest use. I hope I shall not alarm anyone when I say it is no uncommon occurrence in winter time to put 24-inch pressure on the main at Beckton in order to get sufficient pressure in London. All our works are connected with this high-pressure system, with the exception of Kensal Green, which stands quite alone. The advantage of this is that any works in the district apportioned

to it, which has a greater demand than it can supply, can draw from the Beckton main, and put the gas either directly into the district or else into their holders. I do not know why we should stop at 24 inches pressure. After all it is a mere nothing; and I have been thinking the matter over and do not see why we should stop at less than 48 inches. Everyone knows that the leakage which takes place is not directly as the pressure, and as long as the mains are examined from time to time there is no appreciable leakage. Considering we have this large system of distribution under pressure, and that our gas is corrected to 60°, so that we have the additional disadvantage, as some people think, of not accounting for the whole of our gas by about 2½ per cent., so if you look at our unaccounted-for gas it is not more than the general run of undertakings throughout the country. I do not know whether Mr. Stevenson has any particulars as to the cost of pumping the gas per 1000 cubic feet. I had occasion to work it out some time ago; and the whole cost of the pumping comes out at 0·2*d.* per 1000 cubic feet. When you consider that by this means you are doubling the capacity of the mains there seems to be a very great economy in this method of distribution.

Mr. W. Foulis (Glasgow): Is the gas at 24 inches pressure delivered into the distributing mains or only into the gasholder?

Mr. Trewby: At the town end it will be distributed either into the gasholders or through the governors into the distributing mains.

The President: I suppose the 24-inch pressure is due to the friction of the main; it is not gasholder pressure.

Mr. Trewby: The resistance is due to the quantity of the gas sent through and the friction of the main.

Mr. Foulis: I may mention that at one of my works, for many years, we have sent out in the winter about 1,000,000 cubic feet an hour through two high-pressure mains, one being about 3 and the other about 2 miles long. The gas is distributed through governors. The discussion will certainly be very useful to me, because I am just contemplating putting down another 4-feet main right into the town, but if I can manage it by putting on a small blower, as Mr. Carpenter has done, I think it will be more economical.

Mr. W. R. Herring (Edinburgh): I think this question of

high-pressure distribution is one that must have occupied the minds of most of us. At the present time the streets are so much occupied with electric lines and cables for tramways and so on, that there is very little room left for us; and we shall have to devise some means of distributing otherwise than by using enormous mains and working at low pressure. At Edinburgh our position is somewhat similar to that of Mr. Stevenson. Our gasholder stations are scattered throughout the district, and we have to supply them by an exhauster from the different works. It recently became necessary to lay some large mains in a new district, as the town is growing rapidly; and the difficulty arose as to getting a main there, as we had to pass through the heart of the city. I found, after enquiry, that we had a high pressure main of 24 inches diameter, supplying gasholders passing near, where we could get a junction, and it occurred to me that we might put down an underground governor and supply it from that point. We did so, and supplied a 15-inch main under these conditions. I may say the pressure in that district is most uniform. The governor is quite a success, and it saved us 1200*l.* or 1500*l.* on laying a new main. We brought an air-pressure pipe back to the works; it actuated the changing device, the governor being probably three-quarters of a mile away from the works. I think this system is capable of enlargement and we shall be almost compelled to adopt it when we get our new works at Edinburgh. The works will be at the extreme corner of the district: and the trunk main going to some of the present gasholder stations will no doubt be utilised to supply district governors from the leading main. Instead of taking pressure pipes back to the works I shall propose the taking of a cottage somewhere on the road where we can put in a superannuated workman. We shall occupy one room with a pressure chamber, the governor being underground in the street and the man's duty will be to actuate it. I am sure this system will save a considerable amount in the cost of the distribution of gas in the future.

Mr. T. Glover (West Bromwich): I do not think this discussion would be complete without mentioning the fact, that an apparatus has been devised for controlling pressure by electric means from a low-pressure system to the works; so that the gas could be started through a high-pressure main and the pressure be kept constant in the district. Such an apparatus

has been devised and is working, and I think would lend itself to the use of high-pressure supply through trunk mains of comparatively small diameter with a constant pressure on the low-pressure mains, which is very desirable for the consumers.

Mr. C. E. Botley (Hastings): I should like to say a word on this question of the equalisation of pressure throughout a district. I have been able at Hastings to obtain uniform pressure without any mechanical means, though there are great differences in elevation. When I tell you that the highest point is about 650 feet above the works level, and that the works are slightly above Ordnance datum, and that part of the district falls below that datum, you will understand how difficult a matter it is to distribute gas over the whole of the district. By a simple means we have overcome that difficulty to a considerable extent, and periodical investigations of pressure show that the variations are not very great, especially at night. In the daytime there is an excess of pressure on the hills; but at night time when the draught of gas comes on, and the consumption increases, it is equalised to a very large extent. It is done in this way. Hastings is a sea-front town with a number of valleys running up to the table land on the top, with side valleys in between them, and ups and downs of various descriptions—in fact, hill and dale all over the place. When the gas rises up a hill of this kind in the big trunk main we endeavour to keep it generally at a high pressure, and we connect the subsidiary streets by smaller pipes—if necessary cutting the main asunder and putting on a short connecting piece. By making connections of this kind, and by watching the pressures, we keep a fairly equal pressure throughout the whole of the district. In addition to this, we have found it an advantage, at the extreme end of the district, instead of putting down what would be considered an ordinary sized pipe for supplying the gas required, to put in a larger pipe in proportion, so that we have a sort of nucleus of gas there which makes a cushion for the incoming gas to work against, and, so to speak, keeps the pressure constant. I have had continuous tests made during the past winter for another purpose, and have been surprised to find within what a few tenths of an inch the pressure could be maintained in a district of this kind without any mechanical means beyond the natural contour of the ground. With regard

to the high-pressure mains spoken of, I should like to ask whether driving the gas would not tend to impoverish it. I should have thought it would have had a tendency to considerably impoverish the gas at the end of the district.

Mr. F. D. MARSHALL (Copenhagen): I should like to ask whether there would be any objection to sucking the gas through the main by means of an engine and exhauster at the far end of the district. I do not mean to suggest that an absolute vacuum in the main should be produced, but I think gas can be sucked through the main more easily than it can be forced through.

Mr. STEVENSON: I think that the capacity of the main would be impaired by the sucking.

Mr. MARSHALL: My suggestion depends on the understanding that the main itself is not used for distributing, but only as a means of drawing gas from the works to an outlying point. The gas might be sucked to this point and then distributed to outlying parts. My friend, Mr. Irminger, is doing what I suggest. He was not able to push the gas through the mains to the point of distribution, but he sucked it from the works, and distributed it through the supplementary stations in a district which he would otherwise be unable to supply. That would get over the difficulty of high pressure in mains, which seems to be rather a bugbear, and which, as Mr. Botley has suggested, might cause loss of illuminating power.

Mr. F. W. CROSS (Leyton): I should like to say a few words with regard to the remarks of Mr. Marshall. In 1895 I read a paper before the Gas Institute at Edinburgh upon the "Equalisation of Pressure in Victoria, Hong Kong." There we adopted the very means the previous speaker has mentioned. We wished to add to our storage capacity, but we could not obtain the land adjoining the works and had to put our holder from 2½ to 3 miles away from the works, the ground between being perfectly level on the sea side. The holder was supplied through the ordinary mains of the district; there were no special mains laid except for a distance of a quarter of a mile close to the new holder. The mains in the district were only 4 inches, so we laid a 10-inch main for a quarter of a mile, connecting up the larger mains with the holder. The gas was supplied from the works during the daytime at a normal pressure of 10 tenths. When we erected this holder we put an exhausting plant in a house adjoining the holder, and drew the

gas through the town mains while the consumption was going on. The increased pressure required at the works was about three-tenths, and we pulled our gas through the town mains without affecting the consumption in the slightest. Half-way on the main we had a gas engine driving an electrical plant belonging to one of the cable companies, and that engine was never affected. It always had sufficient pressure while we were sucking gas through the main into the holder. Most of the speakers have mentioned high pressure; the previous speaker mentioned sucking gas from a holder, and in my case this gas was pulled through an ordinary town main without any other means of supplying the holder, and without any effect upon the distribution. The means adopted also equalised the pressure at the further end of the district, a distance of about four miles, and on exactly the same level as the works.

Mr. S. Meunier (Stockport): I consider this paper is likely to be of great use to all the Members. In the cases that have been cited, both at Sheffield and elsewhere, there is gas distribution at high pressure by special mains, which, fortunately, the engineers have been able to utilise; but it must not be forgotten that, unlike the case of electric light supply (where you have an entirely new thing, and can put up a high-pressure feeder and a low-pressure distributor), gas companies, having been in existence much longer, have in many instances their mains already laid down; and it is not possible in every case to have either gasholders in various parts of the town or distributing stations. Taking my own town, the only high-pressure main we have is one from the High Street to the works, which is practically only a short length going through the immediate centre of the town. This portion does not need any further supply; but we certainly do find great difficulty in keeping up the service to the outlying districts, which are very rapidly growing. The mains have probably been in existence some twenty or thirty years, and now require either enlargement or some steps to be taken to keep up the supply. I am therefore very pleased to hear the paper, as it will save a large amount of money if it is possible to put down a drawing instead of a forcing apparatus somewhere on the outskirts, and get a good quantity of gas. This would enable us to overcome a difficulty which I cannot see a way of accomplishing by any high-pressure mains. As far as leakage is concerned, I have never noticed any in

the one high-pressure main I have, which is 1¼ mile long with 12 inches pressure.

Mr. T. S. LACEY (Pimlico): I happen to be connected with one of the stations of the Gas Light and Coke Company, where we have arrangements for pumping the gas in and out of the holders. In that company we have to regard the whole of our storage of 100 million cubic feet as common property. It would be impossible for us to adjust our supply in winter unless the different stations could interchange. In order to do that, we have holders at the works, and also in other parts of London, where we can not only pump the gas in, but can pump it out at will. It does not matter whether we pull it in or force it in. The use of a fan as a gas exhauster is one in which I am much interested. It is well known to everyone who has experimented with exhausters, that they do not give proper efficiency at any pressure under 15 or 20 inches. When the water pressure amounts to 40 inches, with a good gas exhauster you can get a mechanical efficiency of about 80 per cent. for the entire apparatus, engine and all; but when the pressure falls down to 10 or 15 inches, nearly the whole of the work done is simply overcoming the friction of the apparatus; and I have no hesitation in saying that the mechanical efficiency of an ordinary fan at 10 to 15 inches pressure would be better than the best exhauster. We have to use pressures of considerably more than 15 inches, but nevertheless, the fan is the most scientific instrument we have for pumping gas. It could be done in two steps. You could pump up to 15 inches with one apparatus, and then take it up higher with another. I do not see any reason why a very cheap and compact apparatus like this should not be used for dealing with a large quantity of gas, and I congratulate Mr. Livesey on the step which he has taken—a step which I believe is in the right direction, a new and a sensible direction. Another thing which has struck me, and I think must have struck us all, is that when a 48-inch main comes to us for distribution there is no earthly reason why that 48-inch main should be continued inside the building. If we are going to send the gas four or five miles we may want the 48 inches, but in the buildings the connections might be very considerably reduced, and also the valves, and a large saving effected without in any way sacrificing the efficiency of the plant. With such

an instrument as Parsons' turbine and a fan a large amount of work could be done in a very limited space.

The PRESIDENT: It is very gratifying to find that the subject has created so much interest, and that so much personal experience of a different character has been brought forward. There is no doubt that the proposal to supply gas at a high pressure, as well as to utilise the pressure in the mains to increase their capacity, is a subject capable of application in an endless variety of ways. You may have means to force the gas through a main under pressure, or you may suck it through the mains, and then deliver it at high pressure, or you may, as Mr. Cross has indicated—if the distributing mains are large enough—even extract from them a certain portion of the gas, and deliver it by a driving or blowing machine into another neighbourhood. All the remarks which have been made show one thing, at any rate —that there is no danger to be feared from the use of high-pressure mains. That is a very important point, because as to their economy there can be no question. One thing should be clearly understood, that by adopting high pressure, the pressure of the holders, or even high pressures in certain mains not connected with the distribution, but independent mains, we are not placing the inhabitants of a town and the users of gas in any danger whatever from leakage of gas and possible explosion.

Mr. F. W. STEVENSON: There is not much to reply to. This is one of those cases in which a very short and apparently simple paper has brought forth a great amount of information from other members, and it shows the great importance of meeting together for discussion in this way. I was particularly interested with what Mr. Carpenter and Mr. Livesey said as to driving the gas by a blower, instead of an exhauster, and the greater quantity of gas which can be put through the main. We only put 200,000 cubic feet an hour through a 30-inch main. Mr. Carpenter mentions an 18-inch main through which they are getting 300,000 cubic feet per hour.

Mr. CARPENTER: The main which is delivering 300,000 feet per hour is a 24-inch main, reduced to an 18-inch.

Mr. STEVENSON: There has been a difficulty in my mind about this 30-inch main, whether, when we were making our full capacity, we were going to get rid of it. From what Mr. Carpenter says, there will be no difficulty whatever, because we

shall get a far larger quantity through than we have any idea of. Mr. Trewby asks as to the cost of pumping. I cannot give the cost, as we have not got it out; but it must be very small indeed. The largest item would be the fuel required for raising steam; but the fuel we use costs nothing—in fact, we should have to pay to get rid of it. There was a question raised as to sucking the gas through the mains; but if you are exhausting through a mile of main, and supplying a governor while so doing, you must maintain three inches of pressure, and you lose the capacity of your main. The object of a high-pressure main is to get a greater quantity of gas through the same size pipe. In our own case, where we are peculiarly situated with narrow valleys and numerous watercourses, there is great difficulty in laying large mains—in fact, in the main street from the Neapsend Works it would be hardly possible to get in another pipe. So we are obliged to get rid of the gas there under pressure. With regard to altitudes, Mr. Botley mentions a difference in level of 650 feet, and says he has regulated the pressures by small connections with the main. I have found that plan to be a mistake in Sheffield. There the level of the works is about 170 feet above Ordnance datum, and the district has altitudes up to 900 feet. From diagrams of pressure taken recently on mains at the higher altitudes, I found that during the daytime, perhaps for twenty hours, the pressure is exceedingly high, but for two or three hours, when the consumption of gas is greatest, the pressure is hardly sufficient. Therefore the line I go on now is to lay large enough mains, and then reduce pressure due to altitudes with district governors.

OBSERVATIONS UPON THE CONSTRUCTION AND WORKING OF INCLINED RETORTS.

By E. DRORY.

Although much has already been written about inclined retorts, their installation, cost of working, &c., the Author ventures to communicate some information on this subject, which, drawn from Continental experience, and representing Continental views, may not, perhaps, be without interest.

At Berlin, 26 furnaces with inclined retorts were erected in the course of last summer, and all but two furnaces were brought into action last winter.

Each setting contains 9 retorts 15½ feet long. Unfortunately, neither in Vienna nor in Berlin did the circumstances permit the erection of new retort houses specially designed for inclined retorts, and the existing ones, originally built for horizontals, offer by no means favourable conditions either for ventilation or the manipulation of coal and coke.

At Berlin, in spite of these drawbacks, a saving in wages of 1*s.* 8½*d.* per ton of coal, or about 5000*l.* per annum, was effected, as well as economising nearly the same amount in fuel. A return of 20 per cent. on the capital expended on these benches may therefore be looked for. The average production of gas per retort and per day, was 12,700 cubic feet with Durham coal, and 14,000 cubic feet with an addition of 15 per cent. of Silesian coal, the duration of charge being 4 hours 48 minutes. It is not necessary to enter further into the details of working results and economy, as the cost of labour and materials, and the conditions of working on the Continent differ so entirely from those in England that a comparison is hardly possible. For the benefit of those gentlemen who take an interest in Continental figures, a comparative table, which was compiled three years ago in Vienna, is added to this paper.

The following remarks are restricted to the actual working

and construction of inclined retorts, and embody the Author's experience of nine years. One principle adopted was the avoidance of all expense beyond that strictly necessary to secure good and reliable work, but, on the other hand, free expenditure, where the prospect of economy in labour seemed to justify the capital outlay.

1. *Manipulation of Coal.*—On a works where the slopers form the total, or a considerable part of the gas producing plant, it is advisable, for the sake of security, to have the engines, coal-crushers and elevators, in duplicate. Where there are two parallel rows of benches (as at Berlin), the engines should be placed in a central position, so that one or either is able to drive one or either crusher and elevator, and these latter able to feed either row of benches.

Many engineers will feel quite safe with a single set of apparatus, merely having duplicate pieces of the movable parts of the machinery in stock.

Once, in Vienna, the steam engine driving a coal crusher broke down in such a manner that a repair *in situ* was not possible, the consequence of which being that the whole machinery had to be put out of action for a fortnight. A similar accident might occur anywhere, and unexpectedly (accidents being usually of this kind), either to the engines or elevators, which are the parts of the greatest importance.

Two systems of coal crushers are in use at Berlin and Vienna, viz. with rollers and with jaws respectively. These latter have proved themselves preferable, as they will crush any sort of coal, including the hard Continental and cannel, with almost equal ease, which cannot be said of the roller crusher. One jaw-crusher at Berlin disposes of more than a ton of coal in a minute.

There are also two systems of elevators, the bucket elevator and the hydraulic lift for coal trucks. Where the coal has to be broken, the first one seems to be the handier, as it will automatically draw away the broken coal from under the crusher.

Coal hoppers have been provided above and along the whole length of the benches. The outlay entailed by this arrangement has been considered too high by some Continental engineers, but it is soon repaid by the economy in labour, the transport of coal in front of the hot furnaces being avoided.

For delivering the coal into the hoppers (in Vienna and Berlin) conveyors have been used, as well as trucks running on rails. There is little doubt that a conveyor is the more suitable of the two, and does not necessitate heavily constructed hoppers to carry the rails and trucks, nor require so many men to work it. All the mechanical appliances for coal have proved very reliable, and the wear and tear on them is moderate.

2. *Charging of Retorts.*—When the coal falls from the conveyor into the hopper it forms into heaps, on the sides of which the large lumps tumble down, the fine coal remaining in the middle. The coal in the hopper therefore varies in size. Supposing the charging apparatus to be perfectly automatic, it would require to be continually adjusted to suit the different sizes of coal, and this would be, to say the least, difficult.

The Author, therefore, does not make his charging apparatus of the completely automatic type, but relies, to a certain extent, on the intelligence of the workman. This man, standing on an elevated platform, has all three rows of retorts well under his observation, and can easily control the charging, and after the carbonisation is complete, observe the layer of coke in the retorts. The shoots, which are lifted into the mouthpieces by means of a lever, are made at such an angle that coal of average size will just charge the retorts properly from top to bottom. Such regulating as is necessary is done by the workman with the horizontal slide valve, which is fixed between the measuring chamber and the shoot.

With a little practice, a man will get so accustomed to this regulating work, that he will charge one hour English coal, the next Silesian, and the next again Westphalian coal with equal ease.

It is not desirable that one and the same amount of coal be charged in every retort *coûte que coûte.* Large and dry coal runs down quickly and carbonises easily, and a heavier charge is necessary than in the case of fine and wet coal. In every case the retorts receive the charge of coal necessary to fill them up to the top. It would appear that the difficulty in England is to make the stoker charge a sufficiently large quantity of coal. This is certainly not so either in Germany or Austria. The men retain so much of the discipline of their military service that, as a rule, they do their work conscientiously, especially if there is a good foreman; and as only a

few men are required for charging, it is easy to select the pick of the yard for this purpose.

3. *Manipulation of Coke.*—The successful economical working of an installation of slopers depends in a great measure on the ease with which the discharging can be done, and the coke disposed of.

Different sorts of coal give sometimes very varying results. Silesian and Moravian coal does not swell during carbonisation, and the coke slides out easily when slightly pushed from above. Several coals of the Durham district do not give much trouble, either, although they swell during carbonisation, whereas others make a deal of pricking up from below necessary. The same trouble was experienced with Westphalian coal. As this difficulty cannot well be overcome, there is all the more reason for making the quenching and disposing of the coke as perfect as possible.

Where the working floor of the retort house is on the ground level, and the coke quenched where it falls, the men are greatly hindered by the heaps of coke. On the other hand, where there is a stage floor, and the coke falls through openings into trucks and is quenched therein, they suffer considerably from the steam and smoke, both above and below. Indeed, the men protested against this method in Berlin. It also entails a considerable amount of labour, as the trucks have to keep pace with the rapid discharging of the retorts.

The system which appears best adapted to avoid these drawbacks is the "De Bronwer trough," which is at work at Bruges and the Hague, and in course of installation at Cassel and Charlottenburg, near Berlin. The conveyor in the trough takes away the coke to the heap automatically, quenching it gradually on the way, and sending up the vapour near the front of the benches. Consequently the work at the retorts can be proceeded with without hindrance or interruption.

4. *The Retort House.*—The construction of the retort house is also a matter of great importance. There is no doubt that a considerable economy can be realised, and much can be done for the general comfort of the men, if, instead of the old-fashioned retort house, a construction were attempted somewhat better adapted to the peculiar working conditions of the inclined retorts.

This is by no means an easy task, for the human mind clings

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persistently to the customary and the conventional, and needs time to find the form adequate to the new idea.

The chief thing is to know clearly the main features desirable in a retort house for inclined retorts. The Author's objects in this respect were simply these: protection against wind and rain for the furnaces; protection against heat, smoke and vapours for the men. Obviously, these aims are nearest attained the closer the roof and walls approach the furnaces, and, consequently, the nearer the men get to the open air.

The design of the retort house is a result of the above train of ideas.

The two rows of furnaces, 30 feet apart, and the elevated sides face to face, form, together with the gable walls, a kind of open court yard. The men on the top of the stage floor, who have a good deal to suffer from the heat, being obliged to stand rather close to the furnace, are thus protected against wind, but have plenty of fresh air. On the lower side of the furnaces, above the bottom stage floor, the retort house walls (iron girders in concrete) are built at a distance of only four feet from the furnaces. Sliding doors are provided in front of the retorts, which are pushed aside during the time of discharging. The men, who have no particularly hard work to do, are practically as much in the open air as their comrades in the coal or coke yard, and much prefer this to the smoky retort house. In Vienna, a small roof was at first erected to protect them against snow and rain, but the men soon found that they were much better off in the open air, and asked to have it taken away, which was done. Since which they have worked there several winters and summers with satisfaction. Frost can do no harm, there being no hydraulic machinery to be affected by it, and in the event of a very heavy rain, the charges may be postponed for a quarter of an hour.

In the highest part of the roof, just above the low side of the furnace, an aperture is left six feet wide, the whole length of the bench, which, acting as a chimney, will easily draw away the vapours, as well of the top as of the bottom mouthpieces. At Berlin, where the slopers are built in an old retort house with a semi-circular roof, the top of which forms the centre line of the two rows of benches, the vapours from the furnace stream across the top stage towards the middle, to the great inconvenience of the men.

It is evident that a retort house especially designed for slopers cannot cost much, the covered area being but small, walls and roof very light, and foundations next to nothing; and this fact can but favourably affect the original outlay for slopers as compared with other systems of gas production.

5. *Furnace.*—The adoption of a generator is necessary for a furnace with inclined retorts. The simple firebar system is not to be recommended, as no uniform heat is obtainable thereby, especially with retorts 15 or 20 feet in length. Particular care must be taken in the construction of the setting, as well as of the stays for keeping it in its position. The retorts, the generator, and the regenerator should have separate stays.

It is also very essential that the fuel gas leaves the generator at as low a temperature as possible, so that the arches which have to carry the weight of the setting should not suffer too much. For this it is necessary always to keep a uniform layer of four to five feet of fuel; to keep the generator perfectly tight, so that no air can enter through a leak and cause combustion in the wrong place; and to evaporate about one pound of water, under the firebars, per pound of coke used as fuel.

If the combustion is a dry one, the gaseous fuel leaves the generator at a temperature of about 2500° F. If a sufficient quantity of water is evaporated this temperature will be only 1800° F. In the latter case, moreover, the slag is quite soft, so that the firebars only want cleaning once in 48 hours. The opening through which the generator is fed must be as large as a retort mouthpiece, in order to get the large lumps of coke easily through. The regenerator must be of such ample construction, that the heated air leaves the last flue at a temperature of 1600° F., and the waste gases must not have more than 900° F. when entering the chimney.

As to the interior of the setting, the supports which carry the retorts should not be more than eight inches apart, as otherwise the retorts are liable to crack, and the joints of the retort lengths should be perpendicular, so that they just come in the middle of a support.

The correct distribution of the heat is of the greatest importance. The retorts should not be too hot in one part, especially near the bottom mouthpiece, as otherwise stopped ascension pipes and thick tar in the hydraulic main will be the result.

A uniform heat is secured by covering up six inches of the intermediate spaces of eight inches between the supports on the level of the upper retorts.

By these means a slight pressure is obtained in the furnace, resulting in a uniform distribution of the fuel gas through the relatively small apertures. This is on much the same principle as the rose of a watering pot, which with a high pressure and numerous small holes gives off a uniform distribution of the water, whereas one with relatively large holes and low pressure gives it off in an irregular way. Apart from this, there is a damper in the main flue leading from the generator to the furnace, which allows the fuel gas to be forced either more towards the upper or the lower parts, as may be necessary according to the sort of coal used.

6. *Quality of the Gas.*—The illuminating power of the gas produced with slopers of 15½ feet length is the same as that produced with horizontals eight feet long.

7. *Advantages of the System.*—Inclined retorts have the advantage of being able to produce gas of good quality and in large quantities on a small area of ground. They effect a considerable economy in labour. In a modern, well ventilated retort house, provided with a De Bronwer's trough, certainly not more than five men are necessary for working 180 mouthpieces, including charging and discharging of retorts, and quenching and taking out of coke, and one extra man is sufficient for attending to ten fires.

But the great advantage of the slopers lies in the fact that neither skilled nor heavy manual labour is any longer required in the retort house. The old stokers, who enjoyed all sorts of privileges, and often felt themselves the real masters both of the works and of the situation, have disappeared, and with them a great deal of the engineer's trouble and anxiety. The few men left, knowing that they can be replaced without difficulty, do their best to give satisfaction to their employers, and thereby retain their well-paid and easy work.

It is therefore not to be wondered at that the popularity of slopers and the increased demand for them on the Continent (especially in Germany) is growing apace.

Mr. Corbet Woodall (London): said that when he designed this arrangement in Berlin, inclined retorts were almost

necessarily adopted because the retort house, which was about 100 feet wide, was already exhausted, and it was a question of producing upon the same area at least as much gas as they were then putting out. He found that by taking out the benches which were set at right angles to the axis of the house, and putting in parallel benches, he was not able to get width enough for mechanical stokers, and therefore he put in these two parallel rows of inclined retorts. That at once illustrated one of the advantages referred to by Mr. Drory in his paper, namely, the larger quantity of gas which might be obtained upon the same area. With regard to the house itself, it was quite true that such a house, so built in, did not lend itself very well to ventilation on a large scale where a great quantity of steam and smoke was being given off, but that was a matter which he was quite sure they would be able to deal with after a few further experiments. The necessity for very thorough ventilation was undoubtedly very great with inclined retorts, because the heat upon the charging stage was—at any rate in all the examples he had seen—so considerable, especially where they were placed in the house so that the heat came from both sides upon the men who were engaged upon the platform in the middle, that very special precautions had to be taken to bring to the men a sufficient amount of air for their comfort in working. Of course, it was a different matter when a single bench was placed in a narrow house, such as Mr. Drory described and desiderated in his paper, where the men could be placed on the outer wall of the house, and could have an abundant amount of ventilation through the openings in that wall. One matter which he hoped would receive some attention in the course of the discussion, was the difficulty that had been experienced, he believed everywhere, to a very varying extent, with regard to the creeping of the coal from the upper end of the retort down towards the mouth. He had had under observation for the last four or five months a bench of retorts admirably set and in perfect order, but where the upper portion—from 3 ft. 6 in. to 5 feet—was almost invariably found at the end of the charge to be empty, the coal having fallen down towards the mouth. They got an excessive charge at the lower end, and of course there was great difficulty in burning it off, because of the thickness of the layer, and the effect upon the setting was necessarily bad. The heat at the

upper end became excessive, and the discomfort of the men was thereby increased. This creeping was bad for the work and bad for the men. It had been thought that this tendency to slide existed more in the case of some coals than in others, and it had been suggested to him that morning by Mr. Braidwood—who had had a very large experience with regard to the operating of inclined retorts—that it might have, and probably had a great deal to do with the form of the retort itself. The matter was not one that could be governed by any system—ingenious as many of them were—for charging the retorts, because it was not at the time of charging that the creeping took place, but after the retort had been closed. He had no doubt an explanation would be forthcoming why this sliding happened, and the finding of some definite scientific reason would be a very long step towards finding the means of dealing with it.

THE CARBONISING PLANT OF A MODERN GAS-WORKS.

By F. D. MARSHALL.

In 1896 the writer had the privilege of reading at the Annual Meeting of this Institution a paper on the 'Monier System of Cement Construction as applied to Gas-works,' with a partial description of the coal stores at the Frederiksberg Works of the Danish Gas Company.

Last year, facilities were afforded for describing the method of discharging coal by Hunt's system, storing in the large bins or pockets, and the eventual transport by rail and re-storage in the bins or pockets at the gas-works previously alluded to.

It is now proposed to bring the carbonising plant at the same works to your notice, and, if permitted, the writer hopes at some future time, to complete the series, by describing the coke handling methods employed.

Coal Storage Plant.

For the sake of clearness and sequence, the writer may perhaps be permitted to shortly recapitulate the course of the coal, from the moment of arriving by steamer, until placed ready for use in the retort house.

The coal is lifted, as described in last year's paper, by the 2-ton Hunt's grabs, and stored in the Monier bins or "pockets" at the harbour. This machinery, it may be remarked, has now been in use for some time, and is even more successful than anticipated, the costs of unloading and storing been lower than previously quoted.

Anyone interested in the matter is invited to inspect this unique and labour-saving installation, which will well repay a visit, even to such a distance as Copenhagen.

From the large stores at the harbour the coal is conveyed

daily by train to the smaller stores on the works, which contain a week's supply, or about 1000 tons.

The coal trucks, each containing 10 tons, are specially constructed with flap doors in the bottom. They are run over a pit, and the contents dumped into the same. The coals, after passing the crusher, are elevated at the rate of 1 ton per minute, and deposited by means of the overhead conveyor in the funnel-shaped "pockets" or bins of the store, which were minutely described in the paper of 1897. From the bins, the coal is transferred by the lower conveyor band, to the three elevators supplying the hoppers in the retort house.

At the time of reading the paper describing this machinery, the writer was not in a position to quote exactly the cost of handling and storing the coal by this method. Since then, however, the exact figures have been ascertained, and as they may prove interesting they are given below.

120 *tons of coal are handled by the aid of* 2 *men*; that is to say, they are *received, crushed and stored at the rate of* 1 *ton per minute, and simultaneously removed from the store and conveyed to the retort house at a like rate.*

The train conveying the coal to the works consists generally of from 10 to 14 wagons, containing from 100 to 140 tons, and this quantity, allowing time for shifting trucks, is disposed of in about 3 to 3½ hours.

The installation is successful to a degree, and it has not failed for a single hour since started three years ago. The wear and tear is inappreciable, and the question of labour, sorrowful as it is to say so, is reduced to a vanishing point.

Referring to the matter of prime cost, the question will be asked, can such an installation pay? Here are the figures, based on the fact of the installation having cost complete 3500*l.*, and destined to handle 30,000 tons of coal annually:—

	£
1 man, storing, 3 hours daily, supplying hoppers in retort house and clearing up, looking to engine, &c., 3 hours daily, at 3½*d.* per hour .. .. say, annually	33
2 men shifting trucks, 3 hours each at 3½*d.*	33
Oil waste, brooms .. .. annually	30
2 per cent. depreciation on 3500*l.*	70
4 per cent. interest on ditto..	140
	£306

On an annual quantity of 30,000 tons = 2·44*d.* per ton, for

unloading, storing, supply retort house, and including wear and tear and interest on capital.

Carbonising Plant.

The immediate object of this paper is to describe the carbonising plant of the works in question, which are equipped with a complete and perfect installation of inclined retorts. The writer is, perhaps, one of the pioneers in the adoption of the inclined system of retort setting, for, after a visit to Mr. Coze at Rheims in 1889, he was permitted by his directors to erect an experimental 9-retort oven, heated by a Haase-Didier furnace, at the old Frederiksberg works of the company. This oven was gradually perfected, and eventually, five years ago, the retort house at the Odense works was fitted with an installation of 51 retorts. This installation, proving in the highest degree satisfactory, was used as the model for the retort house at the new works.

This plant consists of 3 benches, each containing 51 retorts (five settings of 9 and one of 6 in each bench), or a total number of 153 retorts. The angle is 32°, and the dimensions of the retorts are 21 inches by 18 inches by 11 feet 6 inches long through the longitudinal axis.

They are heated by tubular generators of a special design, and such is their efficiency that the last year's fuel consumption was 9·5 lbs. of coke used per 100 lb. of coal carbonised, and the heat escaping to the main flue is barely sufficient to maintain the necessary draught; at any rate the main flue is quite black, and the analysis of the escaping gases gives on the average 18 per cent. of CO_2, and about 0·20 per cent. of CO.

It will be noted that the retorts are set entirely with block stones, very few or no bricks being employed, excepting to line the furnaces. The presence of many joints, however carefully made, is a source of weakness, causing settlements, with the result that the retorts lose their alignment, and this is obviated to a great extent by using block stones instead of brickwork. Coupled to this, a less clever man can complete the setting, for, given a good dressing, and the block stones numbered, he sets to work as happily as a child with a box of toy bricks.

It will likewise be observed that there are no baffle walls, no

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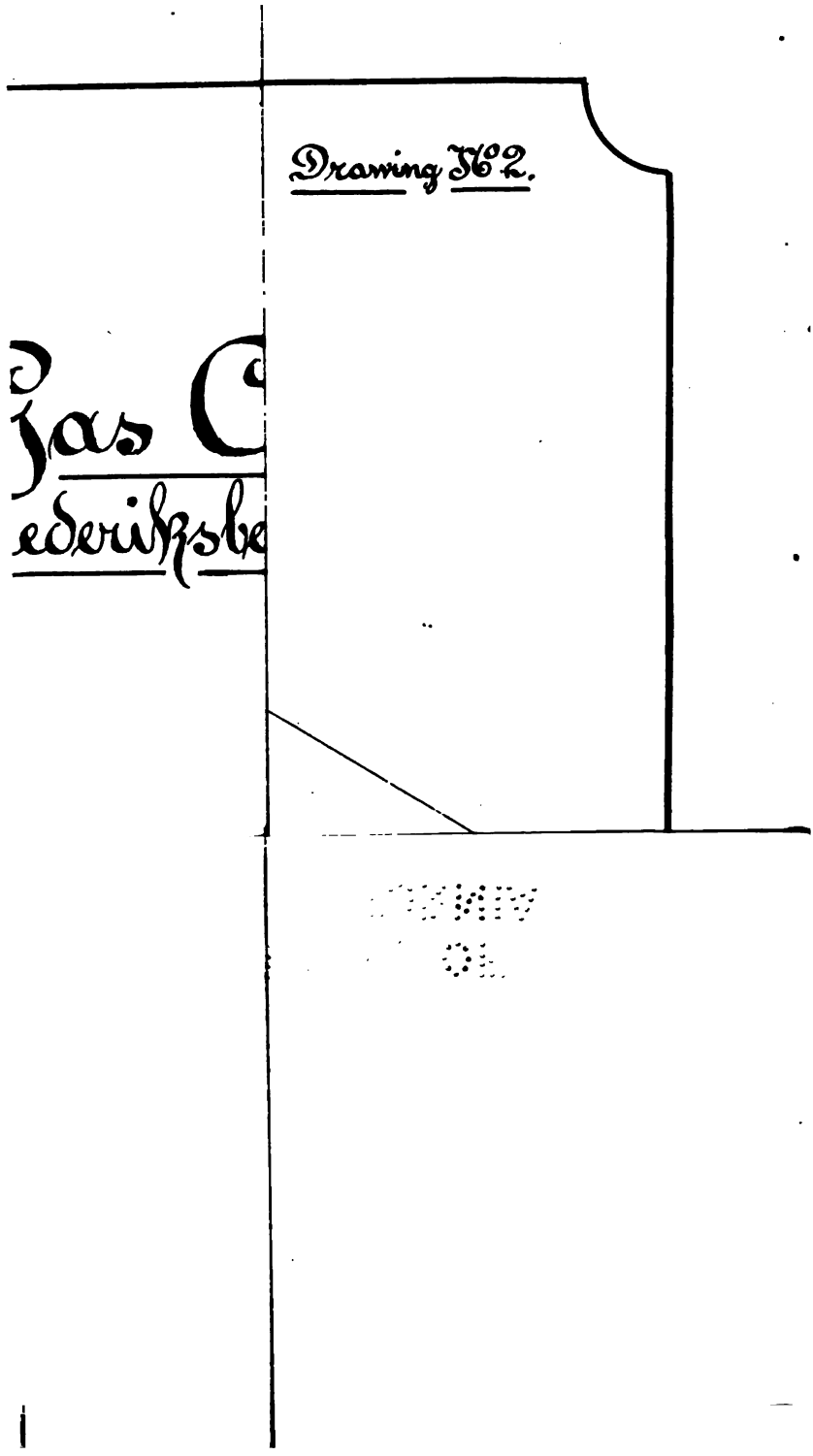
Drawing No 2.



intricate passages, and no nostrils to choke up ; all being open, and easy of observation and access in every part, and the result is a beautiful and uniform heat.

The sides of the retorts are parallel, excepting at the upper ends, where at the mouthpiece, for a length of about 2 feet, they are constricted in a peculiar manner, the first 2 feet having a distinctly greater angle than the body of the retort. This was found by experience to greatly assist the even distribution of the coal, and, what was of greater moment, induced the last portion of the coal, or that with the least speed, to adjust itself properly in the mouthpiece.

It will be noted that the generator is immediately under the setting. This is a controversial question, but, having in view that the ultimate mission of a generator is to save fuel, and not to be an obstruction in the cellar, or a hindrance to coke-handling machinery, the writer is inclined to think that its proper place is under the setting. The retorts are charged from three *fixed* hoppers, one to each bench, fed by the three elevators from the coal bins or pockets. These elevators are supplied by the lower conveyor band previously referred to.

Each hopper contains 61 tons of coal, or 12 hours' supply for each battery. They are filled by the man in charge of the coal store at 6 A.M. and 6 P.M.

The retorts are charged by scoops running on a light railway, three scoops to each bench (one for each tier). As the railway is continuous, the supply can be obtained from any hopper in the event of the hopper attached to any particular battery being out of repair. There is a total absence of conveyors or other machinery in the retort house, and consequently no clatter or noise, all being of the simplest description.

The upper and middle floors are constructed of the lightest steel beams and plates, all of the most gossamer-like description. This is with the idea of saving structural expenses.

The house is well ventilated, the upper or charging doors are jacketed with asbestos, and there is no oppressive heat to worry the men employed.

The greatest possible attention has been paid to the hydraulic mains and over-bench fittings, all caps and openings being fitted with man-hole faced doors and screws. Each hydraulic is fitted with levelling screws, and there are no loose bolts or luted joints whatever. As the writer's old friend, Mr.

John West, remarked, when inspecting the arrangement, "this isn't competition contract work."

A stopped pipe—that man-killing nuisance—is almost unknown, and the professional pipe-jumper is not on our staff.

The entire installation of the benches, including all iron, brickwork and labour, was carried out by the Stettin Chamotte (Didier) Co., and the writer has pleasure in testifying to the thoroughness exhibited throughout.

Working Results.

Stoker's wages, 8 hour shifts, 4*s.* 6*d.* per shift.

1 man charges and draws 24 retorts per shift.

1 man carbonises 10,320 lbs. coal per shift.

1 man produces (at 10,800 cubic feet per ton) 49,680 cubic feet of gas per shift.*

1 man attends to 6 fires per shift, clinkering the same once every 24 hours.

The carbonising wages per ton, including 1 man cleaning lids and tidying retort house, clinkering and cleaning fires, looking to water supply of furnaces, &c., 1*s.* 6*d.* per ton.

This price is from the time the coal leaves the hoppers until the moment the coke is quenched in the cellar.

Each retort carbonises per diem 1720 lbs.

Each retort produces per diem 8316 cubic feet of gas.

The life of a retort is 1000 working days, on the average, and produces during its life 8,316,000 cubic feet of gas.

Each bench requires for fuel, on the average, 9·5 lbs. of coke per 100 lbs. of coal carbonised.

It will be remarked, no doubt, that the retorts are short, being only 11 feet 6 inches long. Respecting the length of inclined retorts, the writer, together with other Continental engineers, holds very strong views. It is believed that where failures have occurred with the inclined system—and it cannot be denied that failures have happened—it can be traced to the excessive lengths of retorts employed. To this fact, too, may be traced the falling off in illuminating power, of which so much is heard in England, and which Field's analysis proves.

* If the furnace cleaner is taken into consideration, the quantity per man per shift equals 33,000 cubic feet.

One of the drawbacks to the inclined system, and, in fact, the most serious one, is the quick accumulation of graphite or "scurf" in the upper ends of the retorts. This accumulation is very marked even in 11 foot 6 inch lengths, and in highly heated 20-foot retorts it must be a much more serious matter. With short retorts there is *absolutely no falling off in illuminating value*, although worked at very high heats.

To remove the pressure at the top of long retorts, the remedy has been tried of taking the gas off at the upper ends; but, as might have been anticipated, "the remedy has proved worse than the disease."

Another point in favour of short retorts is that they can be set in *one length*, the weakness of joints being thus avoided. Setting inclined retorts, even in short lengths, is a very delicate matter, for the whole setting has an inclination to slide forward; and, with heavy 20-foot retorts, this is very appreciable, and ponderous backstaves and retaining anchors are often employed to keep the retorts in their places. With short lengths this tendency to slide is reduced to a minimum, and anchors or backstaves are not required.

Again, the cost of the setting and the house for the long retorts is enhanced out of proportion to the labour saved, the gas produced and the duration of the setting, as compared with the settings of short lengths. This is a controversial matter; but, although the writer might be tempted to increase, under certain conditions, the length to 15 feet, no arguments would induce him to exceed that length.

Comparing the inclined system with power stoking, the writer argues that everything, including common sense, points in favour of the former plan. Elevators and hoppers are needed in either case, but here the similiarity ends. For the inclined system, the retort house may be more cheaply and lightly constructed, and the costly installation of the power stoker, with its power raiser, its skilled labour, and its endless wear and tear, are entirely dispensed with. Power stoking is a costly Colossus, turning an otherwise decent-looking retort house into something between a pit-head and a machine shop. No! Power stoking is an elephantine achievement for the purpose of picking up pins.

Comparing the cost of carbonising per ton, the writer has no definite information as to the results obtained by the power

stoker, but he can scarcely imagine that when *everything* connected with stoking machinery is taken into consideration it can work out as cheaply as stoking on the inclined system.

Regarding the cost of installation per mouthpiece, the inclined system is at present handicapped by monopolies and harassing royalties, but once these hindrances are disposed of, there is no question, in the writer's mind, but that the inclined plan will work out considerably cheaper.

Inclined settings are undoubtedly much more expensive to build than horizontals, perhaps 50 per cent., but against this must be set off the extremely costly power-stoking machinery.

The installation at the Frederiksberg works, including hoppers, elevators, all iron and brickwork, worked out at 103*l.* per retort, and the writer would be glad to know how this compares with first-class stoking machinery.

Personally the writer has nothing but praise for the inclined system, and that it is appreciated by the men is evident from the fact that he has been personally thanked by the Socialist leader of the men's Federation for having lightened their labour. This is very gratifying, and if nothing else has been gained by adopting the plan but a Socialist's thanks, then indeed we hold a proud and enviable position.

DISCUSSION.

The PRESIDENT: We have heard two very interesting papers on the all-absorbing question of inclined retorts, and I hope the discussion will be a full one in every sense.

Mr. FRANK LIVESEY: I, unfortunately, was not present to hear the whole of the papers, though I have glanced through them. One important question raised by Mr. Marshall, is the length of the retort. All admit there must be a limit to the length of an inclined retort; for few have attempted lengths of over 20 feet, and those who have tried have not been very successful. It is evidently easier to charge a retort 11 ft. 6 in. long than one 20 feet, as where there is a tendency in the coals to slip there will be more trouble with the longer retort. The desire to use the longer retort is great, as the labour costs are practically the same for 7½ cwt. or 5 cwt. Mr. Marshall speaks of slipping

coals; and Mr. Carpenter has also had some unpleasant experiences in this respect and can speak better about it than I can. In the case of a 20-feet retort they have been known to slip to the extent of 4 feet; though the coals have been put in quite evenly through the whole length of the retort, and have remained so for five or ten minutes, they have afterwards slipped down. I have actually seen it take place—the top and bottom doors having been left open purposely. It was thought that the slamming of the door might start the slipping, but this was not the case. This does not seem to happen with all coals, and those of our friends who have to deal with Midland coal do not seem to have much of this trouble; but certain Durham coals always slip. One reason, perhaps, why this takes place is the angle at which the retorts are set. Inclined retorts when first introduced were set at an angle of 29° or 30°; but now, in order to get the coke out easier, the angle has been increased even up to 36°, and many are set at 32°. It does not increase the wages very much if a little tickling or poking is required to get the coke out; but it is a much more important matter that the coal should go into the retort as a level charge, and remain so. Is it not a mistake many of us have made trying to overdo it in this matter? As to stoking machinery Mr. Marshall makes the amusing remark that power stoking is an elephantine achievement for the purpose of picking up pins; but if it is necessary to pick up pins, and an elephant can pick them up cheaper than by any other system, I do not see why you should not employ an elephant. If you have plenty of work for a machine stoker to do, and it is efficient, and the men will do a fair amount of work, there is not much difference between the carbonising wages of a machine and inclined retorts, even when you take into account the repairs. But there is the other point to be considered, by using horizontal retorts we know what they will cost; but all must admit that the setting of inclined retorts with conveyors, &c., costs from 25 to 30 per cent. more than horizontals, nearly sufficient to pay for the machines, so the capital charges are nearly equal.

Nevertheless, inclined retorts can be adopted in any works, however small; but not so with machinery, for the capital charges in the former case depend directly upon the retorts set,

but in the latter case the cost is about the same for a large or a small number.

Mr. J. F. BRAIDWOOD (Greenwich): In regard to these papers, I can only say we have been working inclined retorts for the last seven years, doing half our work with them, which is about 1½ million cubic feet per day. There have been difficulties, but we have overcome them. The retorts we are now working are 15 feet in length, and set at varying angles from 30° to 34°. We put them at varying angles, according to the height from which we drop the coal into the retort, and we have put out of sight altogether the discharging, because I have considered from the first that it is more essential to get the coal to lie evenly for the purpose of carbonising than to get the coke out automatically, as it requires very little more labour just to stir with a poker. It is a very favourable way of carbonising, because it works almost entirely by gravitation. There is no elaborate machinery to get out of repair; and no retort-house thrown idle from the breaking down of machinery. You have all the advantages of the machine coupled with the safety of hand labour. When we first started them we were not very successful; only bringing the wages down from 2*s.* 8½*d.* to 1*s.* 11*d.* The next benches brought our wages down to 1*s.* 8*d.*, then to 1*s.* 4½*d.*; now they have come down to 1*s.* 2½*d.*; and I hope the next will come out at 10½*d.* I see no reason why this should not be done. I am as much in favour of inclined retorts as ever I was—in fact, rather more so than when I started. Everybody will find some difficulties at starting, but they will be overcome. As to stopped pipes we do not know what they mean. We have not had a pipe stopped since we started with them. We have carbonised 300,000 tons in them, so we have passed the experimental stage. I should be very sorry to go back to horizontal benches.

Mr. S. Y. SHOUBRIDGE (Lower Sydenham): I should like to ask one or two questions. I notice Mr. Marshall says the retorts are built with stone blocks. I have not heard of any stone in England that would stand the heat of a retort setting. (Mr. MARSHALL: They are fire-bricks.) I should also like to ask how he gets so wonderfully low a fuel account as an average of 9·5 lbs. of coke used per 100 lbs. of coal carbonised. I have had some experience of regenerative furnaces, and some years ago made a number of tests with the Klönne furnaces, in

setting of "nines" built for the Birmingham Corporation, under a guarantee to work with a fuel account of 12 lbs. per 100 lbs. of coal carbonised. I was deputed to see the guarantee fulfilled, and after a week's test under racing conditions, with all the coke in the ashes carefully picked out and returned to the furnaces, it was only just possible to keep under the 12 lbs. Therefore, this average of 9·5 lbs. represents a very distinct advance upon that, and I should like to know how it is accomplished. I should also like to remark upon the statement as to the length of the retorts. I have had some experience of inclined retorts measuring 18 feet on the slope, and have found no difficulty with them whatever. With regard to the falling off of illuminating power to which the writer refers, and of which he says so much has been heard in England, it has been said that one must go abroad to learn what is going on at home. I certainly have not heard of the illuminating power falling off, or that this has been shown by "Field's Analysis." I should be glad to know how "Field's Analysis" proves it. I have worked retorts by themselves for a considerable time, and taken most careful tests of the illuminating power as well as of the make per ton, and have found there is no falling off with either in 18-feet retorts. As to the taking off of the gas from the top end of the retorts, I am not aware that that has been done in England with a view to removing the pressure at the top end of the retort. The difference of level between the bottom and the top ends of a 20-feet retort, set at the angle of 32°, is less than 10 feet, therefore the difference in pressure is not worth consideration. Then with regard to the deposit of carbon, which is said to be a serious matter, I have not found more trouble in this respect than with horizontal retorts. With regard to the alleged tendency of the work to slide, it should be remembered that they are set at the angle of repose, and therefore would stand perfectly well without any backstaves or anchors to keep them in place. In fact, at the Middlesbrough Gas-works there are inclined retorts 20 feet long which have been worked for some years without any front bracing at all. As to the cost of setting, the writer states that inclined retorts are more expensive to build than horizontal retorts, perhaps 50 per cent. more. I have taken a careful account of the cost of building both kinds of retorts, and my experience is that it is more expensive to build horizontal than inclined retorts.

The PRESIDENT: That is, taking the whole of the cost?

Mr. SHOUBRIDGE: Yes; that is, built under the same conditions, with regenerator furnaces, in a stage-floor house. Of course, I am not comparing them with a horizontal bench built on the ground floor. I must say I cannot agree with Mr. Marshall in his humorous remarks with regard to stoking machinery. Stoking machinery is not beautiful, but it is exceedingly useful and ingenious; and the cost of working by it is practically the same as by inclined retorts. There is a considerable field for both; and seeing that machinery has done so much for us in the past, it is somewhat ungracious to refer to it as Mr. Marshall has done. I have been particularly struck with the figures given by Mr. Marshall of the handling of coal at his works, and I congratulate him upon the exceedingly good results obtained. With regard to Mr. Drory's paper, I was astonished to hear of the great saving which he has effected —viz. 1*s.* 8½*d.* per ton—which is more than has been achieved in England. He also says he has economised nearly the same amount in fuel. I take it this economy is due to the use of regenerator furnaces, and not to inclined retorts. With regard to the creeping of the coal, I have not found that to take place with Lancashire coal. I have used coal of all sizes, and have not found it occur. I imagine it must be due to some peculiarity in the Northumberland coal. The difficulty, however, is not insuperable, and I have no doubt special means will be adopted to overcome it by those using this coal. Of course, the angle at which the retort is set affects the result considerably; but with an angle of 32° I should hardly expect it, even with the fine coal that comes from Northumberland. However, Mr. Livesey's careful experiments prove that it does take place. That is one of the difficulties which will have to be overcome; but I do not consider it is an insuperable one, by any means.

Mr. C. C. CARPENTER: I have considered the matter brought most prominently under our notice by Mr. Woodall in connection with the use of inclined retorts, which is a very serious one indeed. The South Metropolitan Company has put up an installation of inclined retorts at the Bankside works, and if it is assumed that one of the conditions of proper carbonisation is to maintain a level layer of coal from one end of the retort to the other during the process of carbonisation, then inclined retorts

as we have them set are incapable of dealing with half the kinds of coal that are got from the Durham and Newcastle district. Only one-half of the coals when put in in a regular and even layer will remain so during the process of carbonisation; the others slip down to a greater or less degree. What we have to do as gasmakers is to get the maximum value from the coal that we carbonise, and at present we are not able to do that at Bankside. The retorts are 20 feet long, and are at an angle of 32°. The carbon question is a serious one. The retorts will run for no longer than three weeks without scurfing. At the end of that time they have to be scurfed, in order to get the coke to run out without too much tickling. That experience is confirmed by Mr. Marshall in his 11 feet 6 inch retorts. The question arises on finding this carbon on the roof of the retorts, Where does it come from? It must be decomposed gas. It is gas that should have passed up the ascension pipe; it must be gas which has given up its carbon and has remained on the crown of the retort instead of going up the ascension pipe and into the meter. I am interested in noting the emphatic way in which Mr. Marshall states that 11 feet 6 inches was the proper length of the retort. If "prodded," Mr. Marshall would extend the length to 15 feet, but wild horses would not drag him further. From that it may be assumed that the ideal condition Mr. Marshall lays down is to have retorts 11 feet 6 inches long. If this is a necessity in maintaining the standard of carbonising as high as we have now, it will be a serious consideration in setting out our retort houses. In days gone by a great deal has been made of the fact that a great increase of retort capacity is possible with inclined retorts, but if we have to cut them down to 11 feet 6 inches much of that advantage will certainly be done away with. As to the coal creeping down, other people, it would seem, have experienced that difficulty, as Mr. Drory in his paper lays great stress upon it. He says, "There is a damper in the main flue leading from the generator to the furnace, which allows the fuel gas to be forced either more towards the upper or the lower parts, as may be necessary according to the sort of coal used." That is equivalent to saying that the coal he was using varied so much as to render it necessary to alter his damper; he had to send more fuel gas to the top to burn the coal there, or to the bottom to burn it off down there. A carbonising plant of that description is, in my opinion, very far

from being an automatic one. Mr. Marshall has also spoken about machinery. Of course, Mr. Marshall's paper was quite an *ex parte* one in favour of inclined retorts, and he looks upon machinery with very great horror. But I do not think that Mr. Marshall has taken altogether a fair view of it. At Vauxhall we have two kinds of stoking machinery, the last and most efficient being the Arrol-Foulis. These machines are operated in a large house with 200 retorts. Each charging machine has its own elevator, which takes up coal from the floor of the retort house as it goes along the stage, or when standing still—according to its own requirements. The coal may be dumped down from a barrow at the back of the machine, and the machine will pick it up and deliver it in regular and even layers in the retorts. I have taken out the cost of carbonising in the same way that Mr. Marshall does in his paper. I have taken the stokers' wages at 4*s.* 6*d.* per shift, and the men at Vauxhall work in eight hour shifts, just as Mr. Marshall's did. I have added on the cost of the Klönne furnaces and the cost of quenching the coke, the men being employed at the same rate as Mr. Marshall's, and I find that the cost of carbonising under these circumstances comes to 10·11*d.* per ton of coal. This figure compares with Mr. Marshall's very high figure of 1*s.* 6*d.* per ton. If coal can be carbonised by machinery for 10·11*d.* per ton of coal, what is the justification for putting down plant which will do it under precisely the same conditions (so far as I can see) for 1*s.* 6*d.*?

Mr. MARSHALL: Does that include wear and tear and maintenance?

Mr. CARPENTER: No. I have not included any wear and tear; neither does Mr. Marshall.

Mr. MARSHALL: We have none; we have no machinery.

Mr. CARPENTER: As far as I can see, the money eventually spent on wear and tear of machinery is spent by Mr. Marshall's plan in the first place on the extra cost of inclined retorts. Mr. Marshall speaks of power stoking as "an elephantine process for the purpose of picking up pins." But this self-contained charging machine, which will pick up its coal from the floor and put it into the retorts in a regular and even layer, weighs 12 tons, and it deals with 140 tons of coal in 24 hours. Is 12 tons an unreasonable weight for an apparatus that will handle 140 tons weight of coal in 24 hours? As to the cost of

the machinery—the drawing and charging machine, the hose reels, the engines and boilers, and the hoppers to carry the coal on the stage—it is 4000*l.*, representing on 200 retorts an outlay of 20*l.* each; which, taking the cost of erecting 20-feet retorts at 52*l.* per retort (the amount the South Metropolitan can do them at), and adding 20*l.* for the cost of machinery, gives 72*l.* You can thus have retorts 20 feet long for considerably less than Mr. Marshall. The 20-feet retorts will carbonise 3136 lbs. of coal in the 24 hours, as against Mr. Marshall's 1720; so that the comparison is as between machine-operated retorts 20 feet long, at a cost of 72*l.* per retort, which would carbonise 3136 lbs., as against a scheme which cost 103*l.* and which will deal with 1720 lbs. in the 24 hours.

The PRESIDENT: Will you tell us whether you have included the removal of coke in that 10*d.*?

Mr. CARPENTER: I have based my comparison on Mr. Marshall's figures, which include the quenching of the coke.

Mr. C. HUNT: I am disposed to agree with Mr. Carpenter that, if the case for inclined retorts had to rest on Mr. Marshall's paper, it was not a very strong one. I am much surprised at the figure Mr. Marshall has given as the cost of working the inclined system with his low rate of wages. I have not gone into the cost of machine charging so fully as Mr. Carpenter has, but may say that our total carbonising expenses with the use of machinery shows week by week only slightly more than the figure Mr. Marshall has mentioned; and this total includes many items which Mr. Marshall has not mentioned, viz. the firemen, and all incidental expenses of the retort house, including the "professional" pipe pumper. I should, therefore, be somewhat reluctant to adopt the inclined system, if I were not fairly assured that the figure for carbonising can be brought down lower than that of Mr. Marshall. I do not propose to join in the controversy as to the desirable length for an inclined retort, except to say that, having had more experience on the point, I feel that so far as carbonising is concerned, if the system is worth anything, it was as good for a long as for a short retort. Opinion is, however, divided on the subject, and further experience appears to be desirable. Mr. Marshall's arrangement appears to be a most complete one, his aim being to effect every operation automatically. Naturally, therefore, one compares it with the ordinary English mode of working. Mr. Marshall brings his coal to a

breaker, then elevates it to a store, distributes it with a conveyor, then drops it on to another conveyor, which takes it to another elevator, which lifts it to feed the retorts; and thus each ton of coal has to be elevated and conveyed twice over in order that the small quantity of coal which has to be taken from stock may be dealt with automatically. The usual English method is to bring the coal to the breaker as it arrives, and elevate it straight into the hopper of the retort house, and only the quantity which has to be put into the stock is dealt with twice. Assuming that out of the 30,000 tons of coal dealt with yearly by Mr. Marshall's arrangement, 1000 tons were stored, the cost of taking up this coal and bringing it to the breaker might perhaps be 6*d.* per ton. To save this 6*d.* on 1000 tons, Mr. Marshall elevated and conveyed 29,000 tons at a cost of perhaps ½*d.* per ton, and it is easy to calculate on which side the advantage lay, to say nothing of the unnecessary amount of machinery employed by Mr. Marshall's method. I fail to see any advantage in doing the work twice over, if this involved a greater cost than the simpler method; and I also fail to see that it is inevitable. If it be so, that must be fatal to the arrangement, but I am disposed to think that, had Mr. Marshall worked out his scheme a little more thoroughly, he might have avoided what appears to me to be a most serious defect. I should be glad to know if the De Bronwer coke conveyor mentioned in Mr. Drory's paper is used anywhere with inclined retorts, or whether it is simply an idea of the author's that this form of conveyor is suitable for the purpose. It appears to me that the use of conveyors with inclined retorts is a somewhat different problem to that of those used with horizontal retorts. With the latter, the quantity of coke to be dealt with is comparatively small, and is to a great extent under control; whereas in all the successful inclined retorts I have seen the coke comes out with a rush, and I imagine that the conveyor requires to be specially constructed in order to cope with it properly.

Mr. R. Brown (Cambridge): With reference to Mr. Drory's paper I am somewhat surprised he relies upon the intelligence of the workmen for the amount of coal put into the retorts. I look upon the success of this system as being due to the fact that the charges are under the direct control of the foreman, and that the workmen have nothing to do with it. When the

charges are set by the foreman, the workmen have only to pull a lever. I certainly think Mr. Drory's measuring chambers cannot be of the latest type. With regard to the length of the retorts, I am going in for 20 feet, but if I was a nervous individual, after listening to Mr. Carpenter's experience, I should go home more sorrowful than I came out. But I am still confident, with the coal I use, Yorkshire Silkstone, that I shall have no trouble whatever.

Mr. CARPENTER: There is not so much trouble with Silkstone coal as there is with coal wrought in the Newcastle and Durham districts.

Mr. J. WEST (Manchester): It is hardly necessary for me now to advocate stoking machinery, as there are so many who have used it who can speak for themselves. On referring to Mr. Drory's paper on inclined retorts I find he gives us the saving in wages; but this has only partial value, because we do not know what it cost him on the old system, and he does not say what it now costs him on the new. Perhaps Mr. Woodall will give us some information on that point. Mr. Marshall tells us it has cost him 1*s.* 6*d.*, but I take it that he does not include the getting in of the coal or the removal of the coke, and several other matters. Neither does he mention interest on outlay. If those items can be separately given, and also the interest on the increased capital cost of inclined retorts as compared with horizontals, it would be interesting, because it appears that the two methods of carbonising coal have both to rely upon machinery to some extent. It appears to me that the cost in detail should be very accurately given. For my own part I am very pleased to find that some figures have now been given. Statements have been made, but there has been a very great want of real figures that we could rely upon. The best figures that I know, as to the cost of stoking machinery, are those given by Mr. Tysoe not long ago, which included everything from the taking of the coal from the coal store to the delivery of the coke into the coke yard. There may be an advantage in one works over another; but if we could take it in that way, it would prevent a great deal of difficulty in finding out the real cost of carbonising. The statement which Mr. Tysoe had published some time ago, gave the average cost of the different kinds of stoking machinery which were then being used, at

1*s.* 5*d.* per ton, including all these charges. The wear and tear is, of course, an item in connection with inclined retorts which has not yet been given. Then there is the elevating and conveying machinery, which applies to one system as much as to the other. I have had the honour of seeing Mr. Marshall's admirable works, and I look upon them as a model works. He has had the opportunity there of erecting complete new works, and there is no doubt he has done it in a very admirable manner. The elevating and conveying machinery I had the pleasure of making for the Danish Gas Company, under Mr. Marshall's direction, and there is no doubt that it works well. In Mr. Drory's paper I was much struck by the question of ventilation. There is no doubt it applies both to the horizontal and the inclined system, but more to the inclined. From the humanitarian point of view I cannot make out how anyone can advocate the inclined system so much as is done. A great deal may be done to secure ventilation. The system I adopted a few years ago was to leave at the back of the retort-house a cavity of 6 inches. Of course, this can only be done where there is no coal store. When the coke was thrown down into the vaults, I found the steam did not come down as it did formerly upon the men, but flowed up under the arch and gradually crept away. The other day I was at the President's works looking at some inclined retorts he is putting up, and I may say he has made provision for ventilation in the same way. He is also arranging, in connection with the inclined retort installation, a conveying plant which has, no doubt, a great deal to do in connection with the economy of the system, by getting the whole of the coal delivered and the coke brought away by the aid of machinery. In his case he does not allow the coke to go down into the vault, but draws it along the front of the retort in a long wide trough. At any rate, I believe in that case as much economy as can be produced by machinery will be produced at Manchester under the President's arrangement. I do not take very seriously what Mr. Marshall says about the colossal structures. It is only a figure of speech, and will not hurt you very much if you keep your temper. I am one of those who believe in the survival of the fittest, and, although I hold a very peculiar position, it is immaterial to me which goes to the front—whether inclined retorts or stoking machinery—as I can make something out of either. There is no doubt whatever but that

Mr. Marshall's arrangements are very good; and, I must say, while on the Continent I was very much impressed with the idea of all those continental gentlemen who are using inclined retorts, that we must have short retorts. The idea abroad is that we must not go beyond 15 feet, while some are using 12 feet, and are talking about 11 feet. But when you begin to decrease the length you will increase the cost of the retorts.

Mr. WOODALL: They are reducing the cost.

Mr. WEST: I am not certain I am not with you. Having seen some of the work in Mr. Marshall's works, and other works abroad, I am not certain that the shorter lengths carbonise the coal better than the long retorts. I should not like to express a decided opinion upon it, but I certainly think it is a matter which should be tested in some of the larger works. Of course, the great stumbing block which Mr. Carpenter has first thrown into the way respecting inclined retorts is a difficult one to get over. For myself, I have observed this for some years. I suppose it is twenty years since I first made experiments with Mr. Carpenter of Sheerness in connection with inclined retorts. We found that, however nicely we planted the coal in the retorts, it did at a certain temperature begin to slide. That is the chief reason why it was given up. I do not think it would apply to the Midland and Lancashire coal so much as the Newcastle coal. At Salford we do not find any of that sliding of which Mr. Carpenter speaks. What I do say is, that these things have got to be proved up to the hilt, and let us have all the proof we can. Naturally, as an "old fogey," I am inclined to stick a little bit to the old system, but at the same time I hope I am inclined to advance as prudence may dictate. I look upon the system of horizontal retorts as the positive system of working, because the coals remain in the place where they are put; the inclined system I regard as a speculative one. Favourable statements have been made about the system, but we have not got detailed figures that we can rely upon, and therefore, while the thing is in doubt there is certain to be this criticism going on as to the cost of the installation and the ultimate advantage of it. In one important respect the matter has still to be cleared up, and that is the question of the units of light. You want to convince some of us that you get the same units of light out of the coal by the inclined system as you do by the horizontal system. There are statements in this

paper that the illuminating power is the same, but that does not quite tally with what Mr. Carpenter tells us about the deposit of carbon. The light must be deposited there, and it would be an advantage if a committee of the Institution would investigate the question and settle it for the benefit of the community. It is a nice point, but it is an important one, where you are being measured up and tested very accurately.

Mr. W. R. HERRING: It is already known that I am an advocate of the inclined retort system. I am quite satisfied it can be made a success; but there are local conditions in every works, which must be considered, which will present their own difficulties, and which must be overcome. We have heard of the serious question of the coal sliding forward; and I would like to ask Mr. Carpenter whether he has tried mixing the coal. He admits that one half of what he uses has this tendency; and I should like to know if he has experimented with using a certain percentage of the other half which does not slide. I think it is quite possible that the Durham coal has a great tendency to become almost a fluid mass in carbonising, and that the process of fluxing gives a tendency to creep, in the same way as lead laid on a sloping roof will gradually creep down to the eaves. I think that may have something to do with it, but perhaps by mixing the coal we can overcome the difficulty. As to the question of relative cost, it is very difficult to get comparative figures. In the first place, the question is, what will be the relative difference in your own works? because there are no two works alike. The labour conditions will be very different. At one works it may be possible to get half as much again out of the workmen as in others, where they will not stand any extra work at all. When I was at Huddersfield I knew that I should be stirring up a hornet's nest if I tried to impose any additional labour on the stokers, so I was very careful to start cautiously. For some considerable time before the inclined retorts were started I had careful note made of the actual duration of the physical labour of the stokers at ordinary work, and I adjusted the work on the inclined retorts so as to come to about that, and set the men to work with a margin of 15 or or 20 per cent. in excess, so as to allow a little bit to knock off. Ultimately we settled down to the same period of time as with the old system, and by that means we were able to save 1*s.* 3*d.*

per ton on our carbonising wages, which we could have saved by no other means. That was the measure of advantage to ourselves. Where I am now we have machinery, and we do not save more than $\frac{3}{4}d.$ per 1000 cubic feet, because the advantage of working by machinery as compared with hand charging is only comparable where the men work under similar conditions as to duration of labour. What I should wish to point out is the difficulty of making these statements as to cost. The thing wants to be comparative at each works. Those who have started inclined retorts can say what they have saved as compared with the former system; and these, in my opinion, are the only reliable figures. I can point to gas-works where shovel charging, even at the present day, would knock either charging machinery or inclined retorts into a cocked hat, simply because the men are satisfied to do much more work. They work twelve-hour shifts, and have other considerations from the company. With regard to Mr. Marshall's paper, I must say that at the time he read the paper on coal stores, &c., I could not quite see the necessity of the system. I do not believe in putting coal into stock one week and taking it out the next. I think it is better to put down stock for an emergency and leave it there. In that case I think Mr. Marshall could have kept a reserve stock, and carried the whole of the coal up practically with one elevator. He puts it into an overhead hopper. This is also done in England, in many cases; but he has to transfer it from the hopper into a traversing shoot, and then to travel the coal along again to the retorts. I do not believe in that system; it is not scientific, to my way of thinking. Once start mechanically manipulating the coal we ought to take it where we want it, instead of into a large hopper such as the one described. The cost of a continuous trough right along the bench would be practically the same as these large hoppers, and you save the men's time in traversing it in small parcels, and consequently both labour and money. As to the ventilation of the house, that is a matter which has been spoken of by one or two gentlemen. The new house at Huddersfield was built purposely for inclined retorts; and I had no difficulty in that respect. If you will look at the diagram you will see we had 1 foot 9 inches in front of the drawing side of the retorts between the brickwork and the stage; and in the walls outside we had several large openings communicating with the yards. In front of the retorts we

had a traversing screen against which the coke abutted when it fell out of the retorts. In consequence of this, a current of air was drawn in under the stage through the openings; it passed up this space in front of the stage, and carried all the steam and smoke clear up into the roof without revolving round the heads of the workmen. I must say the ventilation of that house was very satisfactory—a thing which, I quite agree, should be. As to the length of the retorts, that is a question of great interest to me. I am so far satisfied that inclined retorts are the best system, that I have advised my commissioners to put nothing else down at our new works. I am debating in my own mind whether to go in for 15 or 20-feet retorts. I have had a somewhat large experience with 15-feet retorts, but as has been remarked by others, I am very much tempted to go in for the longer ones, as they are charged with the same physical labour. With this object in view I have been to inspect several installations at work in this country, and I can see no reason why 20-feet retorts should not be adopted. There are works where they have been in use for some four or five years, and why Mr. Marshall refuses to be convinced and go beyond 15 feet I do not know. Of course there may be something in this question of the fall in illuminating value. A gentleman, who has 20-feet inclined retorts, wrote to me some time back saying he had been working them for two years, and suddenly found a fall in illuminating value. He asked me if I had found the same result. I wrote back and pointed out that the fact of working two years without any difficulty surely indicated a defect somewhere else than in the system; and ultimately he found some joints in the condenser tubes had sprung, and he had been drawing in a little air. That is the case of a town where the gas is very rigidly tested; the corporation and the company being antagonistic, and the company has the unit of light very carefully measured against it. With regard to carbon accumulating, of course it must have come from the gas; but it is quite evident to me that there must have been far more pressure in the retorts than was necessary. We found the same difficulty at Huddersfield, if we had a high pressure and did not relieve it; but if we ran with a very light seal, and kept the exhauster well going, the accumulation of carbon was practically no more than a horizontal setting. I maintain it can be regulated by the running of the exhauster rather than anything

else. There is just one other question which probably may have troubled some as to the various methods of charging the retorts. I may say I am of opinion that it is necessary to have the measuring chamber so arranged, that whether you are going to discharge 5 or 6 cwt. of coal into the retort it must pass the mouth of the shoot in the same period of time or you do not get a level charge. If it takes two seconds to charge a 15-feet retort with 4 cwt., and it is intended to increase it to 5 cwt., this 5 cwt. must be discharged equally quickly from the chamber or you do not get a good uniform layer. To do this we introduced a slide valve into the bottom of the measuring chamber, and when we wanted to adjust the weights we adjusted this valve. This was very successful indeed. We had no trouble with the creeping of the coal either.

The PRESIDENT: I think we have had a most interesting discussion this afternoon, and one which should be very useful. We have had the opinions of a number of gentlemen, in addition to the authors of papers, who have worked inclined retorts, and who know something of what the advantages are and what the drawbacks are. We have also had the advantages and drawbacks set out as against those which appear in connection with stoking machinery; but we are not yet in a position to draw any definite or decided conclusions as to the merits of the two systems. I must say that I feel myself very much in sympathy with many of the remarks Mr. Herring has made. It seems difficult, if not impossible, to make comparisons between the expenses which are found to occur at one works and those which are found to occur at another works, in a different part of the world, working under different conditions. It seems to me the only way to settle this definitely, as to whether the inclined retorts or the horizontal retorts when charged and drawn by machinery are the most economical, would be for one works to have two retort houses fitted up with the same number of retorts—one on one system and one on the other—using the same materials and comparing them under the same conditions. A good deal has been said as to the 20-feet retorts. I suppose there are gentlemen who have had 20-feet inclined retorts, and found the results in illuminating power not so good as they anticipated. I do not doubt it may be so, but their names have not been mentioned; and I cannot see where this reduction of the illuminating power is to come in. In Manchester

we have been working for six years 15-feet retorts—that is, just half as long again as the old 10-feet retorts. But the gas from the 10-feet retort used to go up one pipe, and the gas from the 15-feet retort up one pipe. There is 50 per cent. added to the length; but we do not hear of any reduction in the illuminating power due to this fact; nor do I see why there should be if the length were increased to 20 feet. I have been experimenting on these lines, and have come to the conclusion that I can afford to work retorts 20 feet long. I have not yet worked them, and therefore cannot tell you whether I have done right or wrong. As to the matter of carbon, my own experience is that there is so much variety in the quantity of carbon deposited in horizontal retorts, in some cases so little and in others so much, that I do not think any unusual quantity of carbon can be put down either to the inclined system or the length of the retorts. I am quite sure the greatest advantages of the inclined system, if they are to be secured at all, are to be got from the fact of performing all these mechanical operations at one time. I should not believe in lifting coal twice if it could be avoided, or in moving a series of scoops about the house for the purpose of conveying coal from a large hopper to the retorts. What I have endeavoured to do myself is, to put up such an installation that when the coal tumbles out of the truck it will find its way, by mechanical appliances alone, exactly opposite the retort into which it will have to be put, and there will be nothing for the man to do but to pull a lever and let the coal drop into retort; and when the coal is carbonised, the man at the bottom shall open the door and the coke come out. I hope the coke will come out of its own accord; and then it will be removed, also entirely by mechanical means. I quite think that the question of slipping is principally one of a suitable angle for the particular coal used. If we cannot get retorts to suit every kind of coal and always use the same kind of coal, we must draw the happy medium, and make the angle such that it will perhaps be a little too flat for some coal, and perhaps a little too steep for those coals which run like treacle. As Mr. Shoubridge told you, we are not likely to be troubled in that way in Lancashire, as the coals in that district do not show any tendency to slip. The chief difficulty we have experienced has been the swelling qualities of the coal. We have been unable to put large charges in the retorts, because

the coal swelled until it filled up the whole of the retort from top to bottom, and it was very difficult to get the coke out. I will now call on Mr. Woodall to reply on behalf of Mr. Drory.

Mr. CORBET WOODALL: In replying to the discussion on behalf of Mr. Drory, I may say we are now in the comparatively happy position of having eliminated the questions that have hampered decision with regard to inclined retorts—questions of construction, of durability, and so forth. These, at any rate, are now relegated to a limbo from which they will not return. The questions remaining are rather those of first cost and the incidental charges for interest, and the working expenses compared with horizontal retorts, whether worked by power machinery or not. That the system as a system works satisfactorily we now have abundant and sufficient evidence. I regret that Mr. Drory has given so much weight to the difference in the conditions of Continental working from English working, and has not given us the actual figures of his own working prior to the introduction of inclined retorts and since. I agree with Mr. Herring that throughout the country there will be special conditions attaching to special installations, that will always make the figures of individual works of value to an Institution like this. I do not think we need ever be afraid of multiplying statistics for fear of repeating ourselves and having a plethora of knowledge so gained. At present the coke conveyor is not in work at Berlin. Mr. Drory desires to have it, and will probably shortly be able to instal it. Consequently the good results anticipated from its operation have yet to be realised. As to the furnaces I do not think, with regard to this particular installation, or any other, that there is very much to be said on the question of furnaces *qua* inclined retorts. Any good system of regenerator firing will be equally economical, whether applied to the heating of inclined retorts or to the heating of horizontal retorts. I cannot say definitely whether or not there is any creeping in Berlin, but I believe that in any case it is relatively slight in comparison with that which they found in connection with some Durham coals. With regard to Mr. Marshall's paper, I wish to ask him what is intended to be shown by the table of costs. We have here a statement, reduced to the smallest possible denominations, of the men employed in the working on an installation, the expenditure upon oil, waste, sundries, and charges for depreciation and for interest.

Was this intended to compare with the accounts of a company working with horizontal retorts? Depreciation at 2 per cent. I must take exception to, unless there is the usual abundant provision for repairs and maintenance out of revenue from year to year. Two per cent. depreciation is a negligible quantity. As to the 4 per cent. for interest, while it covers the actual cost of raising the money, it is not sufficient to compare with the interest paid by a gas company upon the capital invested in its retort house. I assume that the charge of 103*l.* per mouthpiece at Friedricksberg is for the retort benches only, and does not cover the retort house.

Mr. MARSHALL: Although this has been described as a controversial and *ex parte* paper, it is the result of many years' experience. Mr. Hunt said that I should have given more thought to what I have done; but if Mr. Hunt knew the years I have been speculating on these works, and the hundreds of miles I have travelled, I am sure he never would have made that speech. Every bolt and every nut put into the installation have been the result of years of careful experiment and trial. The installation was perhaps not cheap—but we have Unionists and Socialists to deal with. I have made a bargain with my men, who now serve me very faithfully, and give me a solid day's work for—what I am willing to give them—a solid day's pay. It is the driving of the men, and trying to get more work out of them, that causes trouble. We might carbonise at 1*s.* 6*d.* as against Mr. Braidwood's 1*s.* 2½*d.*, but I cannot do any better. I hope my directors are satisfied—as I myself am, perfectly. Why I dislike machinery is that it is so complicated. My own arrangement is very simple. I raise the coals and I drop them down. Why should we have a machine which requires special knowledge, and which is wasting and wearing itself out day by day, when we can get the same results by a simple process? When these works were designed, one of my directors wrote to me and said: "Have you made up your mind to have inclined retorts; have you given the matter all the consideration it ought to have?" And I replied: "Yes, I have; it seems to me so simple, so feasible in every way; and, after the years we have been experimenting, I do not think I can do better for my directors than ask them to put up the setting." It was an expensive setting, because there were heavy royalties to pay; but when the royal-

ties have lapsed, it will be possible to put up the inclined setting as cheaply as the horizontal. Mr. Hunt and others have also criticised the fact that in my works the coal is raised twice. But that is the best arrangement that can be devised. In winter the works are cut off for a week at a time from the harbour, and we cannot store coal at the works themselves, because the railway cannot give them enough wagons to unload a ship at the rate of 400 or 500 tons a day. But we can unload as much as we like into the stores at the harbour, and then, day by day, we take up as much as we want to supply the works. I must always have at the works a week's supply. In winter, the works being cut off from the harbour for ten or twelve days at a time, I must have that store at the works. I find it to be much cheaper to put the coals down where they are and to elevate them twice. I am quite alive to the two elevations, but when we came to work it out, that was found to be the cheapest way. Assuming that it is an expensive apparatus, I have done what we are all aiming at—I have done away with the men. I have only two men to work the entire coaling arrangement; and less than two men we cannot have under any conditions. Mr. Braidwood gave the cost at his works at 1*s.* 2½*d.*; I am sorry I cannot do it for that. With increasing wages I do not hope to be able to go down as regards price; I am afraid I should have to go up. As to Mr. Shoubridge's remarks respecting the stone blocks, when I spoke of stone blocks I meant hard blocks made of firebrick. As to the point of the length of the retorts affecting the illuminating power, in reply to Mr. Woodall, some months ago, I was able to declare that there had been no such falling off, and that if anything there had been a slight gain. Mr. Woodall then mentioned that there had been a falling off in illuminating power which was supposed to be due to the length of the retorts, and that was his voucher for the statement that in England there had been observed certain indications which were supposed to be due to the extreme length of the inclined retorts. That there is a marked deposit of carbon at the top of the inclined retorts is beyond doubt. Great cakes of carbon are to be found hanging down almost like stalactites, but perhaps on the average we do not get more carbon out of the inclined retorts than out of the horizontal retorts, weight for weight. But it is certain that we do get at the upper end of the inclined retort a very marked

decomposition of the gas, which leads, as Mr. Carpenter has pointed out, to a loss of illuminating power. If there have been failures in England, I can only attribute them to the fact that the retorts have been made too long. I have my own opinion upon that matter, and, as I have intimated in my paper, wild horses will not induce me to go beyond a length of 15 feet. It is an expensive matter to get a 20-foot retort, with the joints properly made and the work properly aligned. Unless the blocks are properly adjusted the joints will expand, and I think the wear and tear in a short retort is much less than in a long one. The life of the short retort is longer, and the result per square foot of heating surface is better than per square foot of the longer retort, because I believe that the gas is decomposed in the last 4 feet of the longer retort, and you do not get it where you ought to get it, namely, in your gasholders. This is only an opinion, but it is an opinion based upon observation during the last seven years. There is no doubt that it is a more expensive thing to build an inclined retort than a horizontal retort, as it requires 30 or 40 per cent. more brickwork, which has to be paid for. As to the creeping of the coal, I think that there is a greater tendency for coal to creep in glazed retorts than in those which are not glazed. Whether glazed retorts are advantageous or not I do not know, but I think they may be disadvantageous, because when they are scurfed for the first time the glaze comes off, and they are liable to bring away parts of the retort as well as the glaze. For that reason I think you should not use glazed retorts on the inclined system. With reference to a remark by Mr. Carpenter, we have found over and over again that fine dusty coal has a greater tendency to creep than coal which is larger, and we had some trouble with one of our coal contracts on account of the coal coming in so fine and dusty. The only way we could use that coal was by watering it well.

Mr. FOULIS: Was not that a disadvantage?

Mr. MARSHALL: It stopped the coal from creeping.

Mr. FOULIS: We usually think that wet coal is detrimental.

Mr. MARSHALL: We did not find it so; at any rate we stopped the creeping, and that is the great thing. Mr. Shoubridge asked how it is that we get such a low fuel account Most of the regenerators in the market give 12 lbs. of coke per ton of coal carbonised, but at Copenhagen, with our regenerator

we can get down to 9·5 lbs. or 10 lbs., and are doing it regularly. There is no doubt that Mr. Carpenter has made out a very strong case for the mechanical stoker. While admitting that the stoking wages may be less with the use of the stoking machine, I do not think that Mr. Carpenter has done the inclined system justice, inasmuch as he has not put on to the mechanical stoker that which is due to it in the way of wear and tear, oil, and such incidental matters. As long as there is no wear and tear on the mechanical stoker I suppose it can do good work. I have mechanical stokers.

Mr. CARPENTER: I have inclined retorts.

Mr. MARSHALL: I have had a mechanical stoker in use for some time, and I determined that it should be the last. Mr. West asked what my cost was into the coke yard. It cost me 1*s.* 9*d.* from the time the coal left the hopper until it was stacked in the yard. Mr. Herring remarked upon the fact that the inclined system lightened labour, and I think that is really the crux of the whole position. If we can do anything to lighten the labour of the men, I think we should do it, and for that reason I have done all I can to adopt the system of inclined retorts, because there is no question that by it a man's labour is reduced to a minimum, and the Copenhagen works would not have been in the proud position of having been thanked by the Socialist leaders if it had not been so. Mr. West has made out a very strong case for stoking machinery. The rule at whist is "when in doubt, play trumps." What Mr. West said in this respect is, "when in doubt, use a West stoker," and no doubt he is quite right.

THE TEN-CANDLE STANDARD LAMP.

By A. VERNON HARCOURT, F.R.S.

THE 10-candle standard lamp, of which the Author has been asked to give an account, is the lineal descendant of two one-candle lamps proposed by him many years ago, and has inherited features from both of them.

The first of these lamps was shown and described at a meeting of the Gas Institute at Sheffield in 1883, and is figured in the Transactions of the Institute for that year.* In this lamp there was burnt a mixture of pentane-vapour with air, formed by allowing air to enter a small reservoir of pentane at some height above the burner, and supplied thence by gravitation. Some of the heat needed for the volatilisation of the pentane was drawn from the lamp by means of a copper bracket attached to the base of the reservoir. The present lamp resembles its predecessor in these two particulars.

A few years later the Author proposed another one-candle lamp, having the same form of burner, with the addition of a cylindrical jacket surmounted by a cone to steady and brighten the flame, and with a metal chimney into which the flame entered at about ¾ inch above the burner. The gas burnt was the vapour of pentane raised by a wick to a point at which it was volatilised by the heat conducted downwards from the top. A very steady flame was thus obtained of the form and size of a short piece of lead-pencil, whose lengthened yield of light could be adjusted by setting the height of the chimney. The actual height of the flame, for observing which a small window was provided in the chimney, might vary, it was found, through half-an-inch or more without affecting the brightness of the exposed portion. There have been adopted from this small predecessor, in constructing the 10-candle lamp: (1) the plan of

* In the same volume, pp. 44 and 155, will be found descriptions of the Table Photometer, which has now been adopted by the Gas Referees, and of the Aerorthometer.

an outer jacket and cone, for supplying warm air to the exterior of the flame; (2) that of a chimney fixed above the flame to steady it, and at the same time to screen off the light of the upper and more variable part; and (3) that of a window in the chimney, for observing the total height of the flame.

Of these devices the most important is the screening off of the top of the flame; and for this the Author is indebted to Mr. Dibdin and Mr. Sugg. Various small improvements in the construction of the lamp, which has grown slowly to its present form, are due to the mechanical knowledge and skill of the Author's colleague, Mr. Vernon Boys; while in every detail its efficiency, and the agreement of one lamp with another, are the result of the excellent workmanship of Messrs. Chance and Co.

Before describing the present lamp the Author may be allowed to refer briefly to two other ten-candle lamps which he had made, and which led to the later design.

To obtain a steady and compact flame giving a light of ten candles, it was necessary to adopt the principle of the Argand burner; it was also desirable to make the lamp simple and portable. For these purposes the domestic lamp, with a reservoir of oil, which might be pentane, a wick to raise the pentane to the point at which it would be volatilised by heat conducted downwards from the flame, and a glass chimney, first suggested itself.

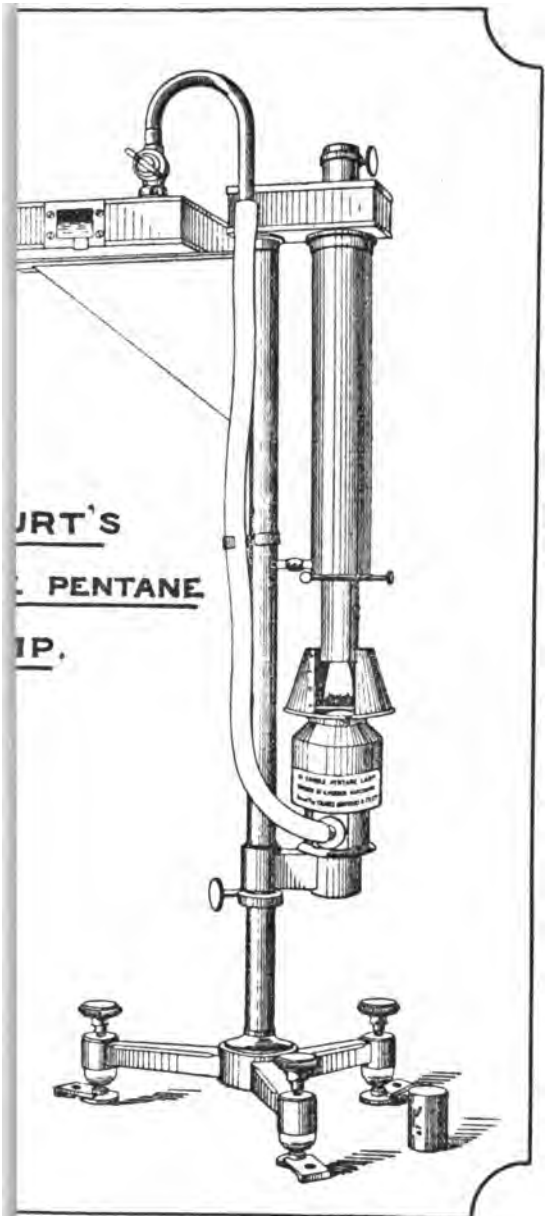
On the planning and making of such a lamp the Author bestowed much time, and, having found experimentally the details of the construction which would produce a constant light of ten candles, he asked Messrs. Chance to make these lamps, and showed and described one of them to the Physical Section of the British Association in 1895. The principal difficulty which he encountered was that of so far commanding the evaporation of the pentane, when no influx of air was used to vary the tension of the vapour, as that the flame could be kept at the desired height, both when the room was hot and when it was cold. This difficulty was not perfectly overcome, and in consequence the lamp required too much watching and turning up or down. A fresh plan was tried. Two small pillars were placed on opposite sides of the reservoir of the lamp and opening into it. In these the pentane was raised by wicks above the level of the burner, whence the vapour flowed to the burner

by gravitation, mixed with air which was admitted at the top of the pillars. By regulating the admission of air the flame could be set at the desired height, and remained fairly constant.

While this lamp was being worked out, further observations were being made with the ten-candle burner proposed by Mr. Dibdin. Unexpected irregularities were met with in a comparison of several of these burners one with another, not very large in amount, but rather too large to be neglected. As far as could be made out, the lack of agreement between the burners was due to differences in the glass cylinders placed round the flame.

In consequence of this experience the Author tried to devise an Argand burner which would give a bright and steady flame without the use of a chimney to produce a current of air. The solid flame of the one-candle burner needed only an external air-current, and this had been supplied by warming air within a cylinder capped by a cone at the base of the flame, and by drawing in air all round the upper part of the flame by means of a tube which the flame heated and entered. The cylindrical flame of an Argand needs also an inner air-current. It occurred to the Author that such a current might be produced by placing round the chimney-tube over the lamp a larger tube from which a branch might bend round and connect with the centre of the burner. The heated air would ascend, and then, losing its heat as it passed away from the chimney-tube, would descend, and would still be under a pressure rather greater than the atmospheric pressure when it entered the central chamber and passed up into the flame.

After various trials it was found that a good flame could be thus produced, the chimney-tube serving also to cut off the variable light of the top of the flame. The requisite supply of pentane vapour was obtained, as in the first one-candle lamp, by supporting a reservoir of pentane upon a bracket at the top of the lamp, and allowing air to circulate over a sufficient surface of the volatile liquid. From this reservoir the mixed gases descend by gravitation to the burner. It remained to discover experimentally what dimensions the parts of the lamp must have to give a flame whose total light was not much more than that of ten candles. If the total light is much in excess of the portion of light desired, the flame is still bright when it passes behind the screen, and a small difference in the height of


URT'S
PENTANE
IP.

the screen materially affects the light shed horizontally. But if the flame immediately beneath the screen is dull, small variations in the adjustment of the height of the screen will not be material.

In the present lamp, the distance between the surface of the burner and the bottom of the chimney-tube which screens off the top of the flame can easily be set to a quarter of a millimeter; but a variation of one millimeter either way makes no measurable difference in the light. Even a variation of two millimeters makes but little difference. The cause of this singular stability in the value of the light, whether the length of the exposed portion of the flame is 45 or 49 millimeters, is not only the relative dulness of the upper part, but that when the chimney is lowered the air-current impinges more strongly upon the central and most luminous part of the flame, thus compensating for its diminished length. A similar compensation, as Mr. Dibdin has pointed out, is the cause of the constancy of the light of the lower part of an Argand flame when the consumption of gas varies, and the cut-off part of the flame is longer or shorter.

The construction of the present lamp will be much better understood from the detail drawings than from any further description. The triangle of blackened copper, which helps to support the shelf carrying the reservoir of pentane, helps also to dissipate the heat which the air-current brings, and which must be taken from it as early as possible on its descending way. For the same reason the reservoir of pentane is so supported that heat will travel to it freely by conduction from the same point, the heat thus got rid of serving to promote the evaporation of the pentane. For setting the height of the chimney-tube, and placing it symmetrically over the burner, the Author uses a solid cylinder of the right length, as in his second one-candle lamp.

When the lamp is to be used in a fixed position it is best to support it upon a tripod with screw, swivel plate and clamp, as shown on p. 19 of the 'Notification of the Gas Referees' for the present summer. If the lamp has to be moved, the necessary stability may be given to its stand by providing three additional branches, which are used only to give support in the three directions in which any instrument resting on a tripod stand is most easily upset. The mode of using such a six-

branched stand is to raise three alternate screws well above the table on which the stand rests, then to level by means of the other three screws, and finally to turn down the alternate screws, which are made to run very easily, till the first increase of resistance shows that their tips are just touching the surface of the table.

Some account must be added of the manner in which the original lamp was adjusted to give a light of 10 candles, and of the evidence (1) that such lamps, as now manufactured by Messrs. Chance, give the same light one as another; (2) that this light is equal to that of 10 standard candles; and (3) that the ordinary variations in the pressure, temperature, and humidity of the atmosphere do not affect the ratio between the light of the lamp and that of the 1-candle pentane standard.

The size and brightness of the flame of the lamp depend upon the diameter of the burner, the space between the burner and the chimney-tube, and the outside and inside supply of air. Suitable dimensions for the burner, and for the chamber around it which produces the external air-current, had been found in constructing the two previous lamps to which reference has been made. The exact and final adjustment to a yield of 10 candles light was made by varying the height of the chimney-tube and those other parts of the construction which produce the internal air-current. After each small change, a comparison was made between the light of the lamp and the pentane unit; and according to the result further changes were made till the required yield of light was attained.

Table I. contains a summary of the experimental evidence showing that the four lamps which have been tested by the Gas Referees are exactly equal. Table II. gives the results of a comparison of two of the same lamps with the pentane 1-candle standard. It will be observed that the means of these testings, which extended over eight weeks, give the value of Lamp II. as 10·01, and that of Lamp III. as 9·99. The mean atmospheric pressure was 30·1 inches of mercury. At this and higher pressures, the mean value of the lamps was 10·03; at the lower pressures it was 9·97. Similar comparisons will show that the small differences in the testings day by day bear no constant relation, and are therefore not due to the variations of atmospheric temperature and humidity which occurred during this period in the room in which the testings were made.

TABLE I.—COMPARISON OF LAMPS.

Values of Lamp I.; the value of Lamp II. being taken as 10.
Each number is the mean of five observations.

1897.								
Nov. 22	9·96,	9·95,	9·97,	9·99,	9·98,	10·05,	10·05,	9·95.
„ 23	10·00,	10·03,	10·01,	9·99,	10·01,	10·01,	10·04,	10·06.

Equally good results were obtained on other days, and when the lamps were compared on an open bar photometer instead of on the table photometer. The light of the two lamps was found to be still exactly equal when the top of the flame of one was set alternately so low as to be only just visible, and so high as nearly to touch the cross-bar of the talc window.

Values of Lamps I. and II.; the value of Lamp III. being taken as 10.
Each number is the mean of ten observations.

1897. Dec. 14 and 15	10·01,	10·04,	10·08,	10·00,	10·02,	9·98,	10·00,	9·98.

Values of Lamp II.; the value of Lamp IV. being taken as 10.
Each number is the mean of 10 observations.

1898. April 12 and 21	9·94,	9·96,	10·01;	10·00,	10·03,	9·99,	9·97,	9·99.

TABLE II.—LIGHT OF PENTANE LAMP IN CANDLES, AS REPRESENTED BY THE ONE-CANDLE PENTANE STANDARD.

Date. 1897.	Thermometers. Wet Bulb.	Thermometers. Dry Bulb.	Barometer.	Light.	—
Oct. 11 ..	13·5	15·0	29·75	10·04	Lamp II.
„ 12 ..	12·4	14·0	29·80	9·94	„
„ 20 ..	15·0	16·5	30·35	10·04	„
„ „ ..	15·2	16·5	30·35	10·17	„
„ 27 ..	12·4	14·0	30·10	10·05	„
„ „ ..	13·0	14·4	30·10	9·96	„
„ 28 ..	12·4	13·6	30·05	9·96	„
„ 29 ..	13·0	14·5	29·90	9·93	„
„ 30 ..	13·1	14·6	29·96	10·00	„
Nov. 1 ..	13·0	14·2	30·17	10·07	„
„ 2 ..	12·2	14·0	30·10	9·96	„
„ 3 ..	12·0	13·8	30·09	10·00	„ Mean, 10·01
„ 11 ..	11·8	13·2	30·00	10·00	Lamp III.
„ 12 ..	12·5	13·9	29·73	9·93	„
„ 13 ..	13·8	14·8	29·50	9·94	„
„ 15 ..	11·9	13·4	29·95	10·04	„
„ 17 ..	12·9	14·0	29·93	10·00	„
„ 18 ..	12·6	13·9	30·13	10·00	„
„ 20 ..	12·1	13·4	30·48	10·09	„
„ 22 ..	12·3	13·8	30·44	10·05	„
„ 24 ..	11·5	13·0	30·20	9·95	„
„ 26 ..	11·2	13·0	30·15	10·02	„
„ 27 ..	11·8	13·0	29·83	9·975	„
„ 29 ..	10·4	12·2	29·45	9·925	„
Dec. 1 ..	10·5	12·0	29·30	9·875	„
„ 2 ..	11·0	12·6	30·05	10·06	„ Mean, 9·987

A TWO-CANDLE PENTANE STANDARD.

By E. LLEWELLYN PRYCE.

In 1876, Professor Vernon Harcourt suggested the use of pentane as a means of obtaining a standard of light to take the place of sperm candles. All to whom accuracy in the measurement of light is an object, are agreed that a more reliable standard than the sperm candle is required, and it is significant of the value of the proposal to use pentane, that, with most of the practicable standards of light which have been devised in this country during the last twenty years, pentane has been employed. The fact that it is a liquid of definite composition, and one which can be readily obtained in large quantity in a sufficiently pure state for the purpose required—whilst, owing to its great vapour tension, it can, either with or without admixture of air, be burned in a gaseous condition—no doubt accounts for the preference which it has received.

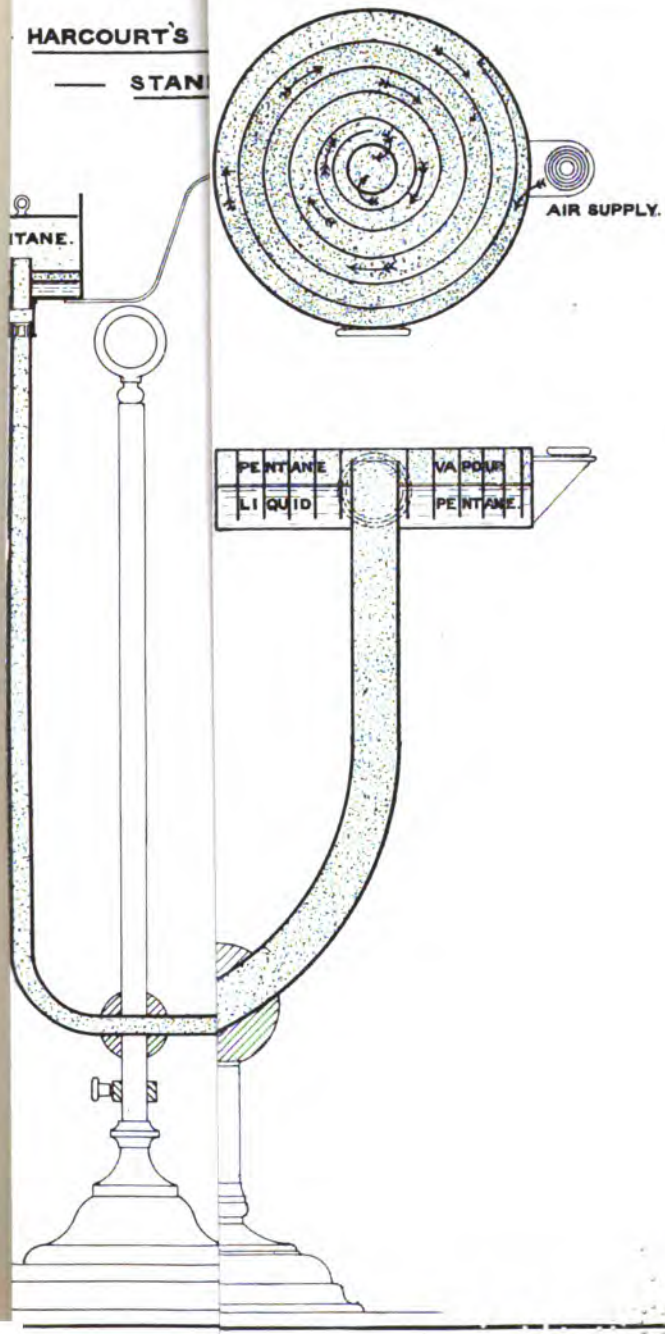
Professor Harcourt's pentane standard, introduced the following year, consists of a burner of very simple construction, viz., a brass tube 4 inches long and 1 inch in diameter, plugged with a brass disc ½ inch thick, with a ¼-inch orifice in the centre at which the pentane gas is burned. A horizontal platinum wire is fixed over the burner at a height of 63·5 mm., or 2½ inches.

Air carburetted with pentane, in the proportion of 1 cubic foot of air at standard temperature, and pressure to 3 cubic inches of pentane, specific gravity 0·62–0·63, when supplied to the burner at the rate of ½ cubic foot per hour, gave a flame 2½ inches high and possessing an illuminating value of one candle. It was found that the maintenance of the 2½-inch flame was most important, since, although small differences in the composition of the pentane, or errors made in preparing the pentane gas, affected the rate at which it had to be burned to maintain the 2½-inch flame, the amount of light given by such flame was of almost constant value.

PE CE'S TWO CANDLE STANDARD.—

HARCOURT'S

STAN



In 1883 Professor Harcourt produced a portable pentane lamp, with which the burner previously described was used; but the gasholder for storing the pentane gas and the meter for registering its consumption—necessary when using the earlier standard—were no longer required; and, as the Simmance 2-candle standard is a modification of this portable pentane lamp, the following description of the latter by Professor Harcourt is given :—

"It will be seen that the flame is still an air gas flame, produced by mixing in the reservoir of the lamp the vapour of pentane with air. The mixture, being heavier than air, floats over the liquid; its composition varying in each layer, from a very rich gas, at the surface of the pentane, to air into which little or no pentane has diffused, beneath the lid. It is clear that by tapping this stratified mixture of gases at the proper level, an air gas containing three volumes of air to one of pentane —the same that is made up in the gasholder—may be drawn off; the same mixture being constantly produced at the same level, by evaporation and diffusion of pentane vapour from below and inflow of air from above. The rate of flow of the gas depends upon the height of the pipe within the reservoir above the top of the burner, the size of the hole drilled through a plug which blocks the pipe at one point, and the density of the mixed gases.

"Any three of the four quantities above named being kept constant, the fourth will be constant. Thus, the dimensions of the pipe and hole having been fixed, if the density of the gas is constant the rate of flow will be constant; and equally—and this is the principle of the lamp—if the rate of flow is kept constant by setting the height of the flame, the mixture will be the same. The permanent adjustment of the length of pipe and size of hole was made by repeated trials, until the flame of the lamp gave exactly as much light as the standard flame. This having been done, similar lamps can readily be produced by measurement.

"The height above the surface of the pentane at which the standard gas is to be drawn off varies with the temperature, and therefore needs to be adjusted on each occasion, and from time to time. It is convenient to have the means of making this adjustment without exposing the eyes to more light than falls upon them when observing (through a hole in a screen) whether the tip of the flame touches the wire above. The

arrangement for this purpose consists of an indiarubber ball filled with water, and connected by a flexible tube with the bottom of the reservoir.

"By pressing upon the ball with a screw, the water can be raised to any required level in the reservoir; the pentane, supplied drop by drop at about the rate at which it is consumed, floats on the surface of the water. So much heat is absorbed by the evaporation of the pentane, that a constant supply of heat is necessary. Such a constant supply is readily obtained by fastening to the reservoir a stout copper wire, which supports a copper disc over the flame. The height and inclination of the disc above the flame may be altered from time to time, according to the temperature of the room in which the lamp is used. A glass T, which connects with the reservoir the supplies of water and of pentane, serves also as a gauge to tell the height of the liquids within the reservoir. A stopcock and bulb beneath the T serve to shut in and keep the small quantity of pentane which is in the reservoir at the end of a testing. A glass collar beneath the burner and another beneath the reservoir serve to prevent the conduction of heat along the brass tube."

The Simmance 2-candle pentane standard is of very simple construction. The burners consist of steatite tubes, each fitted at the top with a brass plug 1 inch in diameter, through the centre of which a hole ¼ inch in diameter has been drilled. Each burner has a stopcock, by means of which the height of the flame can be regulated; and, as the burners can thus be used independently, the standard may be employed as a 1-candle standard if it be required. Two blue glass screens are provided, with cross wires fixed at a height of 50 mm. from the top of the burners, and when the flames are maintained at this height they each possess an illuminating power of one candle.

The carburetter is circular, and is used about half filled with pentane. It is fitted with a spiral plate, attached to the top of the interior but not reaching the bottom. This spiral is so fixed that air entering the opening at the side of the carburetter pursues a spiral course over the surface of the pentane, and becomes completely saturated with its vapour. On reaching the centre of the vessel the carburetted air flows down the tube leading to the burners.

The simplicity of the apparatus is greatly in its favour, no

glass chimneys, by the use of which errors have been introduced into other standards, are used. Neither is a gasholder required to force air over the surface of the pentane, since it is drawn into the carburetter automatically by reason of the falling of the heavy carburetted air down the tube leading to the burners.

The apparatus employed with the Harcourt lamp for obtaining a mixture of air and pentane of definite composition is not required, because air completely saturated with pentane vapour is burned. Moreover, the whole of the flame is used (no cut-off screens being employed), which is an advantage if the standard is to form part of a photometer having a travelling disc-box, as is usually the case in this country.

To use the standard, the plug at the side of the carburetter is removed and the carburetter half filled with pentane. The burner cocks are then opened and a light applied. After the lamp has been alight for about five minutes, little difficulty will be experienced in maintaining the flames at the required height, although, perhaps, they are not quite so stable as could be wished.

The Author regrets that, owing to the shortness of time at his disposal, a thorough investigation of the reliability of these standards under varied conditions could not be made. It would, for example, have been interesting to know what alteration, if any, in the light value of this standard occurs with change of temperature; since there can be but little doubt that in a hot photometer-room, the air in its passage to the burners would take up a larger proportion of pentane than it could in a cold room. The effect of barometric changes is also deserving of attention. It is not believed, however, that any serious alteration in the value of the standard can be due to any of these causes. Experiments have been made as to the variability of the standards amongst themselves, since this appears to be the first inquiry which should be made, although an investigation as to the value of a standard as compared with that at present in use may be considered of equal importance. If, however, a proposed new standard could not be exactly reproduced so that all made are of the same value, further work with it would be useless.

In order to compare these standards, the method of substitution as employed by the "Committee on the Proposed Standard of Light and Temperature of Gas Measurement," appointed

by this Institution, has been adopted; and, as this method is somewhat unusual in photometric investigations, a short description of it may not be regarded as unnecessary. Weighing by substitution has long been practised, and no doubt was of great service in those days when reliable balances were with difficulty obtained. If it were required to weigh 1 ounce of gold by this method, the weight was placed upon one of the pans of the balance and weights and small shot upon the other pan until the one ounce weight was exactly counterpoised. This weight was then removed and gold substituted until equilibrium was once more obtained. It will readily be seen that even if the balance be defective, so that the counterpoise weighs more or less than one ounce, the weight of the gold cannot but be correct, since it has taken the place of the 1 oz. weight.

In testing standards of light by the method of substitution, if three be used, say A, B, C (of course there is no limit to the number), A is placed at one end of the photometer bar, 30 inches from the centre, and B at the other at an equal distance from the centre. After the lamps have been alight for about ten minutes, the height of the flames is adjusted and a number of readings taken. As an example, it may be found that the value of B compared with A is as 1·96 to 2; but it does not necessarily follow that B is actually of less value than A, because the difference may be due to the unequal power of the observer's eyes, to reflection of light in the photometer room, or to other causes which have escaped notice. B is then removed and standard C put in its place. Should this also possess the value as compared with A of 1·96 to 2, it must follow that B and C are of precisely the same value. A and B may now be compared, and the relative value of all three standards accurately determined.

Compared in this way, the following results, which show a very close agreement, have been obtained with three of the 2-candle standards—two of which were kindly lent by Messrs. Alexander Wright & Co., Limited.

If B be taken as possessing an illuminating value of 2 candles, the value of

$$A = \frac{2 \times 2{\cdot}008}{1{\cdot}99} = 2{\cdot}018 \text{ candles};$$

and the value of

$$C = \frac{2 \times 1 \cdot 992}{1 \cdot 988} = 2 \cdot 004 \text{ candles.}$$

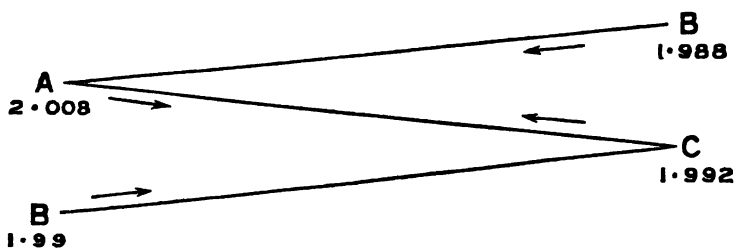
Other determinations have given

B = 2 candles.	B = 2 candles.
A = 2·004 „	A = 2·024 „
C = 1·996 „	C = 2·108 „

The average being

B = 2 candles.
A = 2·015 „
C = 2·006 „

Three standards have therefore been constructed which are practically of equal value, and there should be no difficulty in making others to agree with them.



Standard B has been employed to determine the illuminating power of coal gas supplied from one of the holders at the Birmingham Works simultaneously with the use of the Methven standard and also standard sperm candles; but up to the present a sufficient number of tests have not been made to warrant the Author's bringing them before this Meeting. The average of the results obtained so far, however, shows a very close agreement between the 2-candle standard, the Methven, and also the candles.

The 2-candle pentane standard is recommended for use in experimental researches, for which the present candle standard is quite unsuited.

So much has already been said about the unreliability of the standard sperm candle, that further comment is useless;

the experimental error, it has been authoritatively stated, may amount to no less than twenty per cent. An error of ten per cent. is not unusual; whilst errors of five or six per cent. are frequently obtained. It is most important, therefore, that in scientific work, where accuracy is specially required, a less variable standard should be employed. It would be difficult to conceive the position which the chemical industries of this country would now hold, had the chemical balance been of such defective construction that experimental errors in weighing of as much as twenty per cent. were possible; but, knowing how much depends upon the accuracy of this instrument, one would not be far wrong in saying that it must have been comparatively insignificant.

Although the photometer is not of such predominant importance to the gas-maker as the balance is to the chemist, it cannot but be that the interests of the former—whose primary object is the production of light—have suffered on account of the inefficiency of his standard of measurement; though probably it will not be generally recognised, until some time has elapsed after the introduction of a less variable standard, how great an incumbrance this has been. It will not be going too far to say that some new methods of manufacture, and modifications of plant, by which increased illuminating value is said to be gained, have been received with a certain amount of scepticism, which probably would not have obtained had the means of measuring illuminating power been more exact. Others, perhaps, would never have been introduced.

Reference may also be made to the state of confusion which now exists as regards the value of various enriching materials, since the very diverse statements as to their value are probably more due to photometrical causes than to differences in purity of material or mode of applying it.

The Author therefore recommends the abandonment of standard sperm candles, and the substitution of the 2-candle pentane standard, which, so far as his experience has extended, appears to be one of the simplest and most reliable yet devised.

DISCUSSION.

The PRESIDENT: We have had two very interesting papers on this subject of the standards of light, and we must especially recognise the great pains Professor Harcourt has taken not only to perfect his 10-candle standard, which is now adopted by the Gas Referees, but in explaining it in so full and lucid a manner, and in exhibiting the lamps. I am sure we all very much appreciate Professor Harcourt's services to-day. It is now, of course, impossible that a 2-candle standard should be accepted in any form as the standard, inasmuch as the 10-candle standard is selected, but that does not detract from the usefulness of the 2-candle standard for practical purposes.

Mr. F. LIVESEY: I think we must all echo your remarks that our thanks are due to Professor Harcourt for the immense amount of time and thought he has given to the subject before the meeting. The great improvement in this burner is the abolition of the glass chimney; as not only Mr. Harcourt but also the Institution Committee have pointed out, the chimney was a great difficulty. The chimney had always to have the same side towards the disc if equal results were to be obtained. Of course chimneys are not everlasting, and when one is broken another must be obtained; and there is no certainty that the second will be like the first. The committee have agreed, perhaps it was owing to this defect, that the burner could not be reproduced in quantities to give equal results. There does not seem to be the same difficulty about this instrument; and as gas-makers we are pleased to find that this standard comes so much nearer to the 10 candles than Mr. Dibdin's standard did. We considered Mr. Dibdin's standard gave a value of about 10¾ candles—certainly it was 10½ candles. This one appears to be nearer the mark. I always liked the 1-candle lamp of Mr. Harcourt, and we have used that very often and found it very reliable. That also has no chimney, and, like the new burner, has the top of the flame cut off. There is every reason to believe it will not be subject to the difficulties encountered with Mr. Harcourt's other standard, viz. of smoking at temperatures, say, above 70° Fahr. It is almost impossible to control that lamp unless you are continually turning it down.

Mr. H. E. JONES (London): I am pleased to hear that Mr.

Livesey has tested the 10-candle standard, and found it free of the excess of illuminating value experienced with the Dibdin 10-candle standard. Although I signed the report approving of the 10-candle standard on the Dibdin form, I did it with the reservation that the mode of testing should not involve burning exactly five cubic feet of gas, no matter what might be the constitution of the gas. That part of the report I considered compensated in some measure for the defects of the standard, because of all the tests we made in the Commercial Gas Company's laboratory, it was at least two per cent. above the average candle of the day. There is a view expressed that the candle to-day is not so good as the candle of 1875, when the existing legislation was passed, fixing the illuminating power, and deciding on the London Argand burner. But, however that may be, we had all the way through chiefly Mr. Methven's standard to go by, and I never could find that the candle of to-day has deteriorated as compared with the candle of 1875. I should like to say I have always found Mr. Methven's standard the most reliable one, and certainly the best you can have for daily use in gas-works. With that standard I could find no variation in the candle, either of 1866 or of 1875. I notice in the report to the Institution by the committee appointed to investigate it that they agree that the Dibdin standard was, I think they put it, two per cent. above the normal candle. That is a view I can corroborate from some independent investigations made at the time as a member of the Standards Committee, and I signed the report agreeing to the use of it, subject always to objection to the necessity of having to burn five feet, which has always been an onerous obligation.

I agree with Mr. Hunt's view that we should fill the chimney with flame, and get the best result we can from the gas we are burning, and then correct for the volume required rather than burn exactly five cubic feet. I should like incidentally, although it does not arise on this paper, to speak in high praise of the table photometer, which is now notified by the Metropolitan Referees as the one to be used. The advantage of being able with both eyes to see the shadows of both flames on the same surface is, in my view, inestimable. I have never been able—perhaps owing to defective sight—to reconcile the exact illumination of the screen with the candle at one end of the photometer and the gas light at the other. There always seemed

such a difference in the colour given by the flames as to vitiate the power of equalising the illumination on both sides. Now with the table photometer you stand with your eyes screened from light, and see upon the same ground glass the shadows cast by both the flames, and you can see with both your eyes, or with one eye, as you please, and that gives you a very delicate power of comparing the illuminating power of the respective flames.

Mr. C. HUNT: We are much indebted to the authors of both the papers before us, though, not unnaturally, our interests centres especially in that of Mr. Harcourt and the 10-candle standard, which appears likely to be the standard of the future. Mr. Harcourt has given us an excellent *résumé* of the gradual development of the burner, and has dealt very fairly with the objections attributable to the chimney which were pointed out by the late Mr. Methven and others after the Board of Trade Committee had completed their researches. I am glad to hear that Mr. Frank Livesey is of opinion that the value of the proposed standard is equal to 10 candles.

Mr. LIVESEY: What I said was that it is a nearer approach to it.

Mr. HUNT: The burner seems likely to be accepted as a 10-candle standard. The abolition of the chimney raises another question which I am inclined to think may have next to occupy the attention of the Referees, namely the possible effect of the chimney on the gas, when under test. What is proper in the case of a standard burner, must apply also to the gas which has to be examined.

It appears that the Referees have the power to substitute this standard for the candles, and also to vary the rate of consumption of the gas. If I am not out of order in referring to the recent notification of the Gas Referees, and Mr. Harcourt will not object to answering one or two questions, I should like to ask, in the first place, how the height of the Argand burner above the photometer table has been arrived at. I notice that it has been fixed at about 14 inches. Now in my experiments made recently with a certain form of photometer, it has been found that the height of the flame above the table exercises an important influence on the illuminating power of the gas. With the flame only 11 inches above the table there is a difference against the gas of about three-quarters of a candle as compared with what it is at 18 inches, showing that the air

supplied to the burner requires very careful attention, as otherwise the illuminating power is likely to be depreciated. Another point arising out of the notification is with regard to the limitation of the flame to a 16-candle illumination. I am glad to notice that, even in a limited sense, what I have consistently advocated as to the rate of consumption has been recognised. But supposing one is supplying only 15-candle gas, is the arrangement of the photometer to be varied to agree with this quality? On the other hand, if one is supplying 17-candle gas, is the photometer in that case to be varied? If so, then a different photometer must be constructed for each quality of gas, unless it can be arranged to vary the distance on the table for each quality of gas. At the same time, if it is right to raise the illuminating power to 17 candles, why should it not be right, once for all, to record the illuminating power of the gas when being consumed to the best advantage in the burner, and adjust accordingly. Suppose, for example, 17 candles were fixed as the maximum illumination to be given by the standard burner, then the photometer need only be adjusted to 17 candles, and would be applicable to all qualities of gas. The photometer so arranged would be a universal photometer as regards common gas, for use wherever the standard Argand is applied for testing purposes; and the gas would everywhere be tested under similar conditions. This would fully meet the view I have so frequently expressed on this subject, that the gas ought to be burnt to the best advantage in the burner; and I shall be glad to know if Mr. Harcourt has any objection to the proposal.

Mr. Lacey: I have been testing various 10-candle standards with the object of seeing the effect of any chimney which might be abnormal. It means an enormous amount of work, as one may test a very large number of chimneys and find them all normal. I did find one that was abnormal. It was a 10-candle chimney, and the result of using this chimney on the Dibdin burner, and an abnormal chimney, also on the London Argand, was to make a difference of at least five per cent. from the results given by using normal chimneys on both burners. The use of such a chimney as that is very serious, when it permits of such fearful discrepancies. Therefore I hope that some means may be adopted to prevent the continuous use of an abnormal chimney on either of the burners. The problem of comparing different flames, such as these standard flames is a very diffi-

cult one, for the reason that we are comparing things which are not constant, but are continually moving up and down. You may take two 10-candle standards which agree; but the absolute light coming from which will be found to vary considerably. The candle value of the flame cannot be determined by the use of the standards only, and I have adopted the method which I think a little novel, of having a good secondary battery and an electric lamp. This gives a very constant light, and its deterioration of light was so gradual, that it did not affect the experiment. The lights were compared against this electric light in different circumstances and atmospheric conditions, and it was found that the two 10-candle standards would agree to one per cent., but the light given out would differ to the extent of ten per cent. I find that the flames lose or gain light according to the atmospheric conditions. The London Argand is not affected to quite the same extent as the pentane standard, which is the more sensitive, and consequently under less favourable conditions gives out less light, but not proportionately. I venture to think that if the Argand flame was of the same character as the 10-candle flame, in all probability the variations would be very nearly the same in both, and the atmospheric conditions would not affect the result to the same extent as with the present London Argand. Though this 10-candle standard may be useful, we have not yet arrived at a standard which will give the same amount of light at all times; and when it is found I do not think it will be a flame standard. It seems to me that this standard will answer our purpose very well. The absence of a chimney is a very great point in its favour, and in that way it is preferable to the Dibdin standard, though I hope it is a little nearer to 10 candles than the Dibdin standard has on several occasions been found to be.

The PRESIDENT: I should like to ask if the gas burnt in the flat flame burner was equally affected by the atmosphere and moisture.

Mr. LACEY: I have not tried it, though no doubt it would differently affect the flat flame to the Argand burner.

Dr. COLMAN (Saltley, Birmingham): I should like to add my thanks to Mr. Harcourt for having given us this 10-candle pentane standard, which is likely to be of uniform value, whether it is exactly 10 candles or not. With candles we could not rely on our own tests; and still less could we rely on

those of other people. With regard to the pentane standard itself I have not yet been able to make any experiments, so I cannot add any information as to its being exactly of 10-candle value or otherwise. There are one or two points about Mr. Simmance's 2-candle standard which I should like to mention. We have had it in use at Saltley for the last nine or ten months, and the tests so far as they have gone have been most satisfactory. When I first saw the standard I was much afraid there would be some difficulty in regulating the height of the flame and keeping it constant at 50 mm.; but in practice, even in a room not free from draughts, no difficulty has been found in this respect. I was also rather surprised at seeing that a slight variation in the height of the flame makes so little difference in the results. If you have a difference of one sixty-fourth of an inch in the height of the flame it is very perceptible to the eye; but if both flames are one sixty-fourth of an inch too low or too high, it really makes little difference in the illuminating power. Altogether the apparatus is more easy to handle than I expected. The results of the tests we have made at various times—first with candles and then with this 2-candle standard—come out on an average extremely close. There are the usual variations from day to day between the two; but the average comes out within 0·05 of a candle, and if you reject one or two tests in which the candles manifestly did not burn properly, the average difference is only something like 0·02 of a candle. If the 10-candle standard is adopted universally, there can be no field for the 2-candle standard for official purposes; but at the same time it will be very useful on the works for making coal tests and similar purposes. I think in many works it can well be employed in place of the Methven screen, which has done splendid service, but is affected by the chimney in the same way as the Dibdin standard. With different chimneys one can set with the same Methven screen, testing the same gas, a variation of two to three per cent.; and though it has been much more reliable than candles, I think this 2-candle standard of Mr. Simmance forms a further improvement upon the Methven screen. Another objection to the Methven screen at the present time is the general introduction of carburetted water gas. Where this gas is used it is impossible to use the screen, because it will give much too low results; and, as far as my own experience goes, if this gas be carburetted with pentane, the Methven

screen is subjected to even greater variations than with ordinary coal gas of from 16 to 17 candles. Whether this is due to the fact that the difference owing to variations in the chimney is greater when the short wide slot is used in place of the long narrow one, I cannot definitely say; but I think it probable. Mr. Simmance's apparatus is simple to work; the only point necessary to look after being the amount of the pentane in the carburetter. This should not be allowed to fall too low, the carburetter being kept as nearly as possible half full. If it is allowed to fall too low, the light given becomes rather less than two candles. Another improvement which might be made would be to replace the plug, which has to be removed from the carburetter before lighting the flames, by a stopcock, as in Professor Harcourt's apparatus. With regard to the question of the table photometer, we have found, as Mr. Hunt has mentioned, that a free-air supply to the Argand burner makes a considerable difference in the illuminating power of the gas, and that in many photometers the Argand burner is too close to the table, or the screens are too close to the Argand, thus choking the air supply, and giving a considerably lower result. If the screens are removed, you at once get with the same gas a much higher illuminating power. Of course, with the table photometer there would be no difficulty in arranging for testing any gas other than 16-candle gas by varying the distance of the Argand burner from the screen; and in testing water gas, if this form were used, it would be necessary to make some alteration. That, of course, will only be for our own purposes, and we shall not be bound by any statutory obligations. If we test carburetted water gas by the table photometer as prescribed by the Referees, using a 16-candle flame, it will tell far more against the water gas than coal gas. If the ordinary water gas from 18- to 22-candle power is tested in the Argand burner, it is better to keep the height of the flame so as to give a light of about 18 candles. If the table photometer is universally adopted for the purpose of statutory tests, it will be necessary when testing carburetted water gas, or when testing cannel gas, to modify it in the manner I have indicated. It might, however, be well to continue the use of the bar photometer for these purposes; and I think in that case this 2-candle standard will be of immense use.

Mr. J. W. Helps (Croydon): As one who has had some

little experience with this 2-candle standard, I should like to say I have found it of very great value on the works. Although it is true that now the 10-candle standard is legalised the 2-candle standard cannot be used where statutory obligations have to be fulfilled, yet there are many cases where such a standard becomes useful. The last speaker mentioned that it would be useful for the testing of carburetted water-gas, and I found it particularly useful for that purpose. Where one has to be making practically throughout the twenty-four hours a continuous series of tests, candles are naturally very difficult to deal with, and, as has been said, the Methven screen is out of the question. The point I thought I should find the most difficult in connection with this standard was the shaking of the light in the room in which I had to place it. Our testing room happens to be a room immediately over the engine room, and the floor is subject to a good deal of shaking. I notice Mr. Pryce says he found that a difficulty, but I was surprised to find, under the adverse circumstances under which I had to set the burner, I had no difficulty in regulating the flame and keeping it perfectly steady. I have not made sufficient experiments to allow me to state definitely as to its accuracy with respect to candles, but I am able to say that we got practically the same results at Croydon as we do with the candles. I thought I should like to add my testimony to what has been said as to the value of this standard on a gas-works.

Mr. Vernon Boys (London): I am probably known in the gas world as the recently-appointed Gas Referee, having been appointed at the time when the question of the standard was a serious matter of discussion, and at the time when Mr. Harcourt had either finished or had nearly finished the experiments which led to the designing of his lamp. I have satisfied myself by experiments that the multiple from one candle to ten candles is an exceedingly accurate and true multiple, and in this sense my official conscience is entirely satisfied. I will not say that it is a multiple of 10 candles, because I do not know what a candle is, but it is a multiple of the 1-candle pentane flame. The Dibdin standard was, I imagine, the most perfect thing of the kind at the time, but that is no reason why something more perfect should not be adopted. The chimney has already been sufficiently dealt

with. Turning, however, to the gas testing place, where there is not always too much room, convenience is a point which must not be lost sight of, and a lamp in which no extra supply of air has to be provided is one which has a distinct practical advantage. Further, I think that a lamp, in which the design of the parts upon which the exact measure of luminosity depends is not too complicated and minute, but in which all the forms can be readily and exactly described by reference to a drawing, and can be easily and definitely produced with accuracy in a workshop, is a form which should be adopted. That weighs very strongly with me in forming an independent conclusion, as I consider it is a point in which Mr. Harcourt's lamp has an advantage over its somewhat similar analogue, the Dibdin lamp. Mr. Harcourt has referred to me as having been in some way instrumental in assisting in the development of this lamp, but Mr. Harcourt has been far too good in saying so, as it is literally not true at all. The lamp as it is to be seen now is in every essential feature the same as when I first saw it, and I have done nothing whatever to improve the lamp as a lamp. I have only made one or two minor suggestions of a merely constructional character as to the position of the screws or something of that sort—matters of no consequence to the lamp as a lamp—and I must disclaim all credit whatever for the design of the lamp. At the same time I do not wish to disclaim my full share of responsibility in having accepted it. I am perfectly satisfied personally that the lamp is an exceedingly good one, and that it is a thing of very great merit, and I cannot lose the opportunity of expressing my very great admiration and appreciation of the labours of Mr. Harcourt in producing it. With regard to the table photometer, the details of that have occupied a very great deal of my attention. It is intended to carry the idea of extreme simplicity with freedom from useless expenditure. It contains nothing that is either expensive or difficult to make; everything that has been done has been done with a view to obtain accuracy without expensiveness, efficiency without unnecessary trouble.

Mr. W. Foulis: I agree that we are all indebted to Mr. Harcourt for the pains he has taken and the brilliant result he has produced. I wish to ask whether the table photometer is universally applicable to all qualities of gas, or whether it can be made applicable. In Glasgow we test our

gas, which is 20-candle gas, in a flat-flame burner. If we reduce that flame to 16 candles, we certainly will not get anything like the same result. The question with me, therefore, is whether the table photometer can be adapted to any quality of gas.

Mr. R. O. PATERSON: I wish also to express my appreciation of Mr. Harcourt's kindness in coming before us. I have seen Mr. Harcourt's apparatus in operation, and I consider that the facilities given by the 10-candle standard lamp in conjunction with the table photometer really calls for admiration. It is adaptable to the wants of any one without the slightest difficulty whatever. As to the lamp, I may say that I have experimented with it before the Gas Referees issued their instructions, but in my hands it is not satisfactory, in the sense that it is not a multiple of ten candles. But as soon as the Referees issued their instructions, with the dimensions, I found that the distance of the chimney from the top of the burner was considerably below what was prescribed in the instructions. I have no doubt that the ten candles is to be obtained simply as Mr. Harcourt has pointed out, by the regulation of the distance between the top of the burner and the bottom of the chimney, and I believe that, as Mr. Frank Livesey has said, it is nearly a 10-candle standard.

Mr. WEST: Some years ago, at one of the first of the meetings we had in connection with the consideration of the new standard of light, I made, with the late Mr. Hartley, a large number of experiments with the pentane lamp, and at that time we found it gave more light than a standard sperm candle. This was pointed out, and I am very pleased to find Mr. Harcourt has brought his 10-candle standard lamp nearer than it was formerly to the proper candle power. This has now been accepted by Mr. Frank Livesey and others, therefore I think we may look upon it as a more reliable standard than we were inclined to think it was formerly. In setting up any new standard, we certainly should have a standard of the same value as formerly; and much as candles have been abused, within a good operator's hand you can get a greater degree of accuracy than some have expressed to-day. I have not myself, in experimenting with candles, found that divergence of which we have heard. Although I am not one of those who adhere to the old candles if a better standard can be found, at the same

time we must not forget that it is a standard, if decided upon, to go all over the country; and while it may be very useful to some of our eminent friends in London, where they have chemists to assist them in manipulating the apparatus, in the provincial towns we have small works where something as simple as possible is required. It did strike me, while Mr. Harcourt was describing the instrument, as to how difficult it might be to get a fair accurate test by the man in small works. The fact that the temperature is of great importance may lead to difficulty. I think I understood that as the liquid and gas descend the tube, it must not be overheated, or you would not get the accuracy that was desired. Though Mr. Harcourt, with his sensitive touch, could tell degrees of temperature from the top to the bottom, when you come to some of the hardy sons of toil, their hands would not be of the same velvet texture as his own. I would therefore suggest that we should have something a little more reliable than that. It struck me that we should have a thermometer at the bottom, or at any rate, something more definite than the touch of various individuals, so as to avoid the differences which were found in days gone by when the optics of some gas testers were found to vary.

Mr. W. King (Liverpool): A previous speaker has made a suggestion which may throw some light on the question of gas testing—it is whether the flame of a bat's-wing burner is affected to the same extent by atmospheric and other conditions as the flame of an ordinary Argand burner with a glass chimney. In Liverpool we have to supply gas of not less than 20-candle power in a bat's-wing burner; and the standard burner which is in use there is Sugg's No. 7 steatite bat's-wing—a well-known burner, which was used in London for testing when cannel gas was manufactured. Our experience certainly is not that of many gentlemen present to-day. In the paper reference is made to the enormous difference arising from the use of candles —as much as 10, 15, and even 20 per cent. in various experiments. That is entirely beyond our experience in testing gas of 20-candle power with a flat flame burner. With respect to candles, our experience is entirely opposite to the experience of the speakers to-day. We have not found practically these great differences in using candles; and I may throw out the idea, to which a previous speaker has referred, whether these differences

may not arise from the chimney of the Argand burner rather than from the candles themselves? Like Mr. West, we are not entirely satisfied with the candles; but I do not think they are as bad as they are painted. If we can obtain a perfectly reliable instrument, we shall only be too glad to use it. The remarks I have made are borne out by figures which may prove interesting to the meeting. The Corporation of Liverpool continually test our gas, as a hostile tester, though it must be understood that I do not use that word in an offensive sense. At any rate it is an unbiassed test. Taking our own tests—we make some thousands during the twelve months—they come out on an average at 20·77 candles. The Corporation tester in his last annual report says that 299 tests made at their office averaged 20·87 candles, and 91 tests taken at various points throughout the district, covering many miles of area, give 20·68 candles. These averages were obtained from results having a very narrow range. These figures agree remarkably with our own, and do not seem to point to the use of an unreliable standard. I have the details of the 91 tests, and in no case is the figure below 20. These results may throw some light on the subject of using a flat flame burner without a chimney; and we should be interested to find out whether any gentleman has carried out tests with the bare flame—thus eliminating errors which may arise from differences in the thickness of the glass or obscurity of the chimney, or variations in the draught.

The PRESIDENT: Much of what Mr. King has said was in my own mind, though I did not intend to occupy time by talking about it. The conditions of testing in Manchester are very similar to Liverpool, though we are not watched by a quasi hostile Corporation.

Mr. KING: I did not use it in that sense.

The PRESIDENT: I strongly incline to the belief that with the use of flat flame burners many of the discrepancies found to exist in testing with the Argand burner and low-power gas disappear. Perhaps it is as well that the candle should now be superseded, seeing that so many imperfections have been attributed to it, and that, whether exaggerated or not, it has become somewhat discredited. I am afraid that a good many of the imperfections of the operators are charged to the discredit of the candle. There is at least a temptation to do that. It is, perhaps, well that we should have a standard that cannot equi-

vocate, and if things go wrong it will not be the fault of the standard, but of the tester or the gas. I find that with 20-candle gas, consisting of gas made from coal mixed with gas produced from cannel, it is much more difficult to maintain the candle-power at any one uniform point than to get uniform testings of it. If we could be sure of our gas being always up to 20-candle power, we could depend upon the candle test being near enough for our purpose.

Mr. VERNON HARCOURT: I have to thank the meeting for the kindness with which it has received, and the interest it has shown in, my communication. I was glad to hear the favourable impression which Mr. Frank Livesey had formed of the pentane standard, and Mr. Jones's experience of the table photometer. Mr. Hunt has raised a question as to the height of the burner above the table. My impression is that when the burner is not near the table the height does not make much difference. If the burner were only six inches or so above the table, that might affect the illuminating power value.

Mr. HUNT: I mentioned down to 11 inches.

Mr. HARCOURT: We fix a height of 16 inches, and we hold we are safe there. It is certainly a point to be considered, but I should be much surprised to find that it makes any difference whether we have a height of 16 inches or 26 inches. The actual height adopted with our photometer is I think more favourable to combustion than in the ordinary run of photometers. I have tested many photometers where the flame is not raised so much above the floor of the photometer as is the case in this burner. Also the free access of air all round is certainly in favour of the constancy of the flame.

A question was asked by Mr. Foulis as to how far the table photometer is applicable to gases of greater or less illuminative value than 16 candles. What the Gas Referees had to deal with were the conditions existing in London, where 16-candle gas had to be provided. Elsewhere, if the requirements of a consumption of five cubic feet per hour is retained, the limitation is that determined by the use of the London Argand burner. This burner is only suitable for use with gas ranging from a little under 16 candles to a little over 17 candles. I believe the amount of light you get is proportionate to the quality of the gas within those limits. When you get gas below or above those limits there is a very rapid falling off in the amount of

light you get from the burner. It would be easy to adapt the photometer to gas of any quality, provided it is a fixed arrangement. The simplest plan would be to alter the distance between the photoped and the burner. In the table photometer, as arranged for London gas testing, these distances are to one another as 4 to root 10; and the simplest plan would be to make the two distances one to another, in the ratio of root 10 to the root of whatever was the presumed value of the gas. The fixed distance between the photoped and the London Argand in the present table photometer is 1265 mm.; if a burner of 20 candles were substituted the corresponding distance would be 1414 mm. It has just been suggested to me by Mr. Boys that it would not be difficult to make the same photometer serve for different qualities of gas by having the position of the standard lamp movable. There might easily be placed in position a graduated scale, by means of which the standard might be set in the right position for testing either 20-candle or 16-candle gas while the burner remained fixed. The difficulty is, you would have to change the burner. It may be there is a flat flame burner which would do equal justice to 16-candle and 20-candle gas, but the first necessity is to get such a burner. First we must have a burner suitable to the particular quality of the gas, and put it at such a distance from the illuminating surface as to give the right ratio.

Mr. FOULIS: Would the same table of corrections which has accompanied the instructions serve for both gases?

Mr. HARCOURT: I think some extension of that table would have to be made. There would, however, be no difficulty in extending it to deal with gas of any quality.

Mr. HUNT: Would you object to testing 15- or 16-candle gas with an illumination of 17 candles in the chimney?

Mr. HARCOURT: I do not think there is any advantage in it. I think we should have a truer result by burning the gas so as to get a light of 15 or 16 candles and measuring the rate of consumption.

Mr. HUNT: You would not object if there is no advantage in burning the larger quantity.

Mr. HARCOURT: You burn a larger quantity to get an illuminative value of 17 candles. According to the Metropolitan Gas Acts the gas supplied has to be such as to produce when consumed at the rate of 5 cubic feet per hour in the Argand

burner, a light equal in intensity to the light produced by 16 candles. With such gas we have to compare the gas actually supplied, which may be of slightly higher or slightly lower illuminative value. The comparison may be made either by consuming gas at the prescribed rate and measuring the light, or by varying the quantity of gas burnt till the prescribed intensity of light is attained and measuring the consumption. Mr. Hunt's proposal is to fix neither rate of consumption nor intensity of light, but to measure both when the chimney is quite full of flame. A figure can thus be obtained for the illuminative value of the gas; but it is not certain, nor even probable, that if gas agreeing exactly with the definition of 16-candle gas given in the Acts were thus tested, its illuminative value would be found to be 16 candles. Mr. West has referred to some experiments which he made long ago with Mr. Hartley, in which he found a want of stability in the one-candle pentane standard, and also that its light was rather greater than one candle. I believe the lack of stability was chiefly in the floor of the room in which the testings were made. I think it quite likely that the one-candle flame, as tested by Mr. Hartley, and even as used at one time by Mr. Dibdin, gave a light rather greater than that of the average standard candle. In the account of the table photometer read to the Gas Institute in 1883 I said that the height of the standard flame was to be adjusted by looking at its tip only, and the wire above through a small opening in the curtain. If the tester, instead of thus screening from his sight the body of the flame, looked at the whole of it, he would see as definite a tip as in the other case, but it would not be the same tip and he would set the flame higher, and get from it between two and three per cent. more light. Mr. West has expressed a doubt as to whether fingers accustomed to rough work, to which the manipulation of photometry may have to be entrusted at gas-works, will be sensitive to small gradations of temperature. In constructing and modifying the 10-candle lamp it has been found necessary to observe the effect of different means for cooling the tube through which the heated air descends. But no such observations were needed, nor any particular delicacy of touch, in the ordinary use of the lamp. Turning to what Mr. King says as to the results of the tests he got from candles, it seems to me that you will get results of that kind when you have a large number of tests. It

is only when you have a limited number of tests with candles that you are liable to error, because they vary up and down, and by taking the average of a large number of tests you arrive at practically similar results. The average illuminating power, I understand, was nearly the same at the works and all over the district.

Mr. KING: Never below 20 candles, but the variations were small.

Mr. HARCOURT: Is it that no test gave below 20 candles or the average was not below 20 candles?

Mr. KING: No test with candles ever gave below 20. This shows that candles, however great the objection may be to them as a standard, give very small difference in actual tests.

Mr. HARCOURT: Were the results not much above 20?

Mr. KING: The tests were all above 20 and occasionally above 21. I think the averages were very close together, certainly they did not show much difference. Out of 91 tests taken about the district the difference would not be more than half a candle, as an extreme figure.

Mr. HARCOURT: Between one test and another?

Mr. KING: Yes, taking the average throughout the year. Though there are variations, they are not great variations.

Mr. HARCOURT: That seems to show the great skill of the tester and the invariably high quality of the Liverpool gas. I have to again thank you for the kind reception you have accorded to the paper.

Mr. LLEWELLYN PRYCE (Birmingham): I thank you very much for the kind reception you have given my paper—the first paper I have had the honour of reading before the Institution. I have mentioned that the flames of the standard are liable to waver a little at times; but this will not be found a difficulty in using it, because the moment after this wavering has taken place the readings will be found to be precisely the same as before. As is well known this is very different in the case of candle flames—a disturbance causing them to give increased luminosity; so that, notwithstanding the correction for the consumption of sperm at the end of the test the opposed light is returned of lower value than it would have been if such disturbance had not taken place. I agree with Dr. Coleman in recommending this 2-candle standard as against the Methven

burner, though I do so with some hesitation, on account of the good work which the Methven burner has done. I have used it for many years, and it has saved me an enormous amount of time ; but the glass chimney causes difficulties. I should like to call attention to the fact that it was Mr. W. C. Young, who, in 1891, in a paper he read before the Society of Chemical Industry, first called attention to the irregularities which might take place by the use of chimneys with Argand burners. I may add that improvements will be made in the 2-candle standard which will render it even more serviceable. It is proposed to bring down from the carburetters to the burners two tubes instead of one, and also to place cocks directly under the carburetter for adjusting the quantity of pentane used. These alterations will keep the flames much steadier than they are at present.

A NEW DEPARTURE IN CARBONISING, HAVING FOR ITS OBJECTS THE PREVENTION OF NAPHTHALENE TROUBLES, AND THE PROVIDING OF CHEAP ENRICHMENT.

By S. GLOVER and T. GLOVER.

In the manufacture and distribution of coal gas for lighting purposes, there has been a little modest pride on the part of gas engineers in the knowledge that the article they supplied might always be relied upon when wanted, and that the price per unit of light was low as compared with its competitors.

In spite of the fact that gas has hitherto been the cheapest source of artificial light when used with modern burners, strenuous efforts are constantly being made to reduce the cost of manufacture; this being so, not only where under the sliding scale the possibility of paying improved dividends acts as a healthy stimulant, but also under municipal ownership, where no such stimulant exists.

The efforts made for the cheapening of production have assumed various forms, among which may be mentioned—

The introduction of machinery in the carbonising department, and the use of small coal.

The application of higher temperatures to the retorts, whereby a larger volume of gas is obtained from a given weight of coal.

Improved methods of separating the tar from the gas.

On works where machinery has been installed, it is usually considered unnecessary to use round coal, which before being used must be broken; and the tendency has been to purchase a class of coal which in the days of uneconomical gas-making would have been considered quite unsuitable. Moreover, the practice

of using cannel coal for enrichment has been gradually discontinued, its place having been taken by various substitutes, such as the volatile hydrocarbon vapours obtained from petroleum spirit, oil gas or carburetted water gas.

These modern developments have had a marked effect upon the cost of production, and the selling price of gas, but, unfortunately, the old quality of reliability has been somewhat interfered with, owing to an excessive production of naphthalene, the inconveniences arising from which are only too well known to most of us.

To overcome the difficulties arising from the use of higher heats and cheaper coals, it was necessary at the St. Helens works to use a high percentage of cannel, but as this was found to be an expensive and inconvenient method of enrichment, the Authors were led to look round for a substitute for cannel, and this they believed they had found in the Peebles process for producing oil gas.

That process was adopted at St. Helens in the full belief that it not only produced the cheapest enrichment, but also, under the then popular impression that the rich oil gas would dissolve and hold in diffusion through the coal gas the vapour of naphthalene, which was liable to give trouble.

As stated in a former communication to this Institution, the practical working of the Peebles process fully bore out all the Authors' anticipations so far as the cheapness of enrichment was concerned, and when enrichment could be obtained at such a low cost, it led to inquiries being made for still cheaper coals to produce the bulk of gas at a low rate. The supply was found from some of the slacks in the district. By using these slacks, carefully selected for their coke-making qualities, and enriching the poor quality gas with Peebles oil gas, they have been able to manufacture and deliver into the holder 18·5-candle gas at an average price of something under 7*d.* per 1000 cubic feet, inclusive of all manufacturing charges.

In thus obtaining the cheap gas, however, they found after a time that they had to contend with difficulties which they had not anticipated. Owing to the fineness of the slack coal, and the high temperature employed to carbonise it, there was so much naphthalene produced that the gas was left so heavily charged with that compound as to give a gradually increasing amount of trouble from stopped services.

Careful investigation and research proved that whilst the Peebles oil gas was by far the cheapest form of enrichment, the popular idea that the rich hydrocarbon oil-gas had the power of holding the naphthalene of the coal gas in diffusion, and preventing its deposition in the crystalline form, was altogether erroneous. It was also found that to have any effect upon the naphthalene, it is absolutely essential that the solvent for it should either be in the liquid form, or, if present in the gas in the form of vapour, its vapour tension should be similar to that of the naphthalene, so as to condense along with and carry it away in solution.

It became evident that the use of cannel had performed other functions in addition to that of enriching, and that it had also acted as a solvent and removed part of the naphthalene from the coal gas during the process of condensation, thus modifying the troubles attendant upon its deposition.

The knowledge of these conditions led the Authors to join with their colleagues in devising a simple and convenient process for the prevention of naphthalene deposits, the application of which would not involve a reversion to uneconomical methods of manufacture. The aim of the present paper is to give some account of the process adopted, and the measure of success which has been attained.

The principles upon which the process is based have already been explained in a paper communicated to a kindred Association, and therefore it is unnecessary to go again into their details. It may, however, be desirable to briefly recapitulate their main features.

Coals when carbonised at low temperatures, have their constituent elements arranged into products very different from those obtained from the same coals distilled at high temperatures. At the low temperatures, the hydrocarbon products present are mainly those belonging to the paraffin and olefine series, together with the largest possible quantity of basic and acid hydrocarbons and the minimum quantity of gas. As the temperature rises these low temperature products are broken up and rearranged to form more stable products belonging to the benzole, naphthalene and anthracene series, until, at the higher temperatures employed for the economical production of gas, the paraffin and olefines are present in comparatively trifling quantities, whilst the naphthalene is so abundant as

to practically saturate the small volume of tars and the large volume of poor coal gas, and there is an absence of the necessary solvents for naphthalene in the form of vapours in the gas.

The true causes of the trouble from naphthalene were thus concluded to be due to the lack of liquid hydrocarbons present in the products capable of dissolving the naphthalene out of the gas, and preventing its being deposited in the solid crystalline form.

Cannel coal, from its nature, even when distilled at high temperatures, yields a quantity of the hydrocarbons suitable to absorb naphthalene, or prevent its deposition in the crystalline form. But to employ cannel and condense the products along with those from the coal involves loss, owing to the tars taking up in solution the hydrocarbons which should be left in the gas to act as solvents and enrichers. Furthermore, in consequence of the presence of the large quantity of naphthalene, the power of the cannel products to absorb that remaining in the gas, is to a large extent nullified.

These observations suggested to us the application of the solvent and carburetting hydrocarbons to the coal gas after it has been condensed, when the tars, with the major portion of the naphthalene, have been removed, and it is therefore in a condition for the solvents employed to act on the remaining naphthalene, and for carrying in diffusion the hydrocarbons suited for enrichment, when they are presented to it.

Seeing that when coals are carbonised at suitable temperatures, they produce a rich gas and also hydrocarbon products comparatively free from naphthalene, and suitable for performing the double function of dissolving the naphthalene and carburetting the gas, we were led to anticipate (from the results obtained by carbonising oil at comparatively low temperatures by the Peebles process) that a good practical method of obtaining the necessary products would be to carbonise the cannel at a low temperature, and use the resulting products to treat the condensed coal gas, so as to free it from naphthalene and to carburet it.

To test the correctness of those principles, some preliminary experiments were tried at the West Bromwich Gas-works, and the results obtained led to a more complete trial being made at the St. Helens Works, the apparatus being arranged as shown on the diagram.

The diagram illustrates the way in which the apparatus was connected up, for the purpose of carrying out the process.

The setting of retorts devoted to the work of low temperature distillation is No. 15 in a bench of fifteen settings of seven through retorts, 20 feet long. The retorts in this setting have been made into "singles" by means of a stop built into the centre.

Each bed is fitted with separate hydraulic mains, which are connected to the foul main by means of suitable valves. The valves of No. 15 bed having been closed, a special take-off pipe has been fitted to the hydraulic main to convey the products away whilst still hot.

The products of the lower temperature distillation are thus isolated and are kept from cooling by means of a steam pipe laid inside the main. Those sufficiently volatile are maintained in the state of vapours, while other products somewhat heavier are kept in a fine state of subdivision in the gas. The products are all mixed with the large volume of condensed coal gas into which they are diffused. The naphthalene still remaining in the coal gas is acted upon in the manner previously described, and the gas is at the same time enriched. If we take into consideration the enormous comparative volume of this high temperature coal gas, which, being unsaturated, is in a sense thirsting for these vapours, it can easily be conceived that it will be in a condition to take up, and carry in diffusion, a large quantity of the vapours from the low temperature products.

The connections were completed on December 31st, 1897, and the result of the first three months' working was that the naphthalene complaints were reduced to less than one-third of what they had been during the previous three months. Although, with the varying nature of the weather, the circumstances were certainly more favourable to the deposition of naphthalene, and all the evidence goes to prove that the previously deposited naphthalene is gradually being picked up by the gas as now made, and cleared out of the distributing system, whereas trouble was experienced throughout the whole of last year.

The percentage of cannel carbonised in the setting devoted to its treatment, was 6 per cent. of the total coals used at the time of starting, and this gradually increased, as the settings

using coal were reduced, until in April it was 10 per cent. This was found to be giving sufficient enrichment to raise the high-temperature coal gas from 15·5 candles to 19·01 candles, this being an average of 22 tests. The production of gas per ton has not suffered to any material extent through the introduction of the new system, being over 10,000 cubic feet per ton of coal carbonised.

These results compared with working in the old way, show a saving of upwards of 50 per cent. on the cannel; previous experience showing that, even with higher class coal, 25 to 30 per cent. of cannel had been required to obtain equal results, all other conditions being the same.

By the results obtained in the working of this process, the cost of gas into the holder has been still further reduced.

The process therefore provides a remedy for naphthalene troubles and the cheapest form of enrichment, but where enrichment is unnecessary, the principles of the process can be applied as a remedy for naphthalene. In such cases ordinary coal would be used to supply cheaply and conveniently the necessary solvents.

It should be noted that the average quality of the tar by the new process is not interfered with, being, in fact, better for producing anthracene and benzols, than that derived from a mixture of coal and cannel when used in the ordinary way.

It now remains to give a rational explanation as to how these results are realised, founded upon well ascertained chemical and physical facts.

Many years ago it was demonstrated by Mr. William Young, at a meeting of the North British Association of Gas Managers, that equal quantities of carbon and hydrogen when combined as hydrocarbon gases, or hydrocarbons and free hydrogen, and having varying molecular structures, would give widely different illuminating powers. The combinations, as paraffins, were shown to give the least intrinsic illuminating power, and as the carbon and hydrogen were rearranged into the high-temperature products, such as olefines, benzols and acetylene, both the illuminating power and volume were increased. It was pointed out that each rise in volume and illuminating power was accompanied by a greater amount of heat energy being stored up in the molecules of the carbon and hydrogen, and it was surmised that the increased illuminating power was probably due to this

stored-up energy being liberated as light, at the instant of decomposition in the luminous flame.

Subsequently, in May 1884, Professor Percy F. Frankland, in a communication to the Society of Chemical Industry, showed that olefiant gas, when diffused in certain proportions through non-luminous hydrogen, had its intrinsic luminosity greatly increased, and when a mixture of olefiant gas and marsh gas was made, the intrinsic value of the olefiant gas was increased to a still greater extent.

More recently Professor Lewes has shown that acetylene, a gas having stored up in its molecules a large amount of heat energy, and having an extremely high intrinsic illuminating power, loses enormously in its illuminating power when diffused through certain proportions of hydrogen, marsh gas, or coal gas.

The probable explanation of these phenomena may be that the low temperature products of destructive distillation, the paraffins and olefines, having a low stored-up heat energy in their molecules, take up further heat from the gases through which they are diffused, during the early stages of combustion. The store of heat thus absorbed is given out again as light at the instant of decomposition of the more complex molecules.

On the other hand, acetylene having the largest possible stored-up heat energy, cannot absorb heat from the surrounding gases, but on the contrary, has, at the instant of decomposition, to part with a portion of its stored-up heat to the diluting gases through which it is diffused. It thereby has its illuminating power reduced.

Whatever be the cause, there is no doubt about the facts, and it is thus evident that the constitution of an enriching gas has a considerable influence upon the enriching effect which may be obtained.

Perhaps the best practical evidence on this point is supplied by the Peebles process, where the oil is subjected to destructive distillation, at comparatively low temperatures, and where the main products in the resulting gas are paraffins and olefines. It is well known that oil gas so produced, when diffused through coal gas, has its intrinsic illuminating value practically doubled.

On the other hand, oil gas produced at high temperatures, has for its principal constituents, members of the benzol and acetylene groups of hydrocarbons; such a gas when used as an

enriching agent diffused through coal gas, would have its intrinsic illuminating power only slightly increased.

The same condition holds good in the carbonising of coals and cannels, the gases and hydrocarbon vapours produced at low temperatures having a much higher enriching value than gases produced from similar coals at high temperatures, due to causes already explained.

These facts have only come to our knowledge in recent years, through the introduction and the practical employment of high and low-temperature products as enriching agents. Up to quite recently it was understood that gases, having different illuminating powers when mixed, would yield a mean illuminating power of the gases employed.

Whilst the high enrichment obtained by this process is thus shown to be mainly due to the difference in the constitution of the gases and volatile hydrocarbon products, resulting from the carbonisation of coal and cannel at temperatures suited to the object in view, yet there is also a considerable gain in enrichment value, from the method of condensation employed.

The attention of the gas industry was drawn to the principles involved in condensation more than thirty years ago by the Rev. W. R. Bowditch, M.A., F.C.S., and more particularly to the influence and solvent action of low-tensioned products upon the more volatile vapours, and the loss in the illuminating power which ensued due to this solvent action. He also pointed out that the power of the heavier hydrocarbons to dissolve out the lighter was dependent upon the temperature during the time the heavy vapours were separating out from the gas. The principle was laid down by him that it was desirable to precipitate the thick tar from the gas whilst it was still hot, and thus prevent their absorbing valuable illuminating constituents.

These have been the guiding principles of the industry since that time, and have been applied in many modern works to a limited extent, in a number of ways, with beneficial results for the most part, but accompanied by the drawback that, owing to the removal of the tar at an early stage from the foul mains, it cannot exercise its solvent action upon the naphthalene of the gas. The large amount of naphthalene present in gas made at high temperatures has thus less chance of being absorbed.

The new method of treating the products, explained in this paper, allows of the correct principles being fully applied, and

the full value of both the high and the low-temperature products being obtained; with the additional advantage that a sufficient supply of solvents is provided for dealing effectually with the naphthalene.

It is only necessary now to add a few words in further explanation of that part of the process which deals with the prevention of naphthalene deposits.

For information on the subject of the influence of the temperature of carbonisation on the gaseous and liquid products, the study of the following communications may be commended:—

'Studies in Coal Distillation,' by Mr. L. T. Wright, Society of Chemical Industry, London, 1888.

'Coal Gas,' in Thorpe's Dictionary of Applied Chemistry.

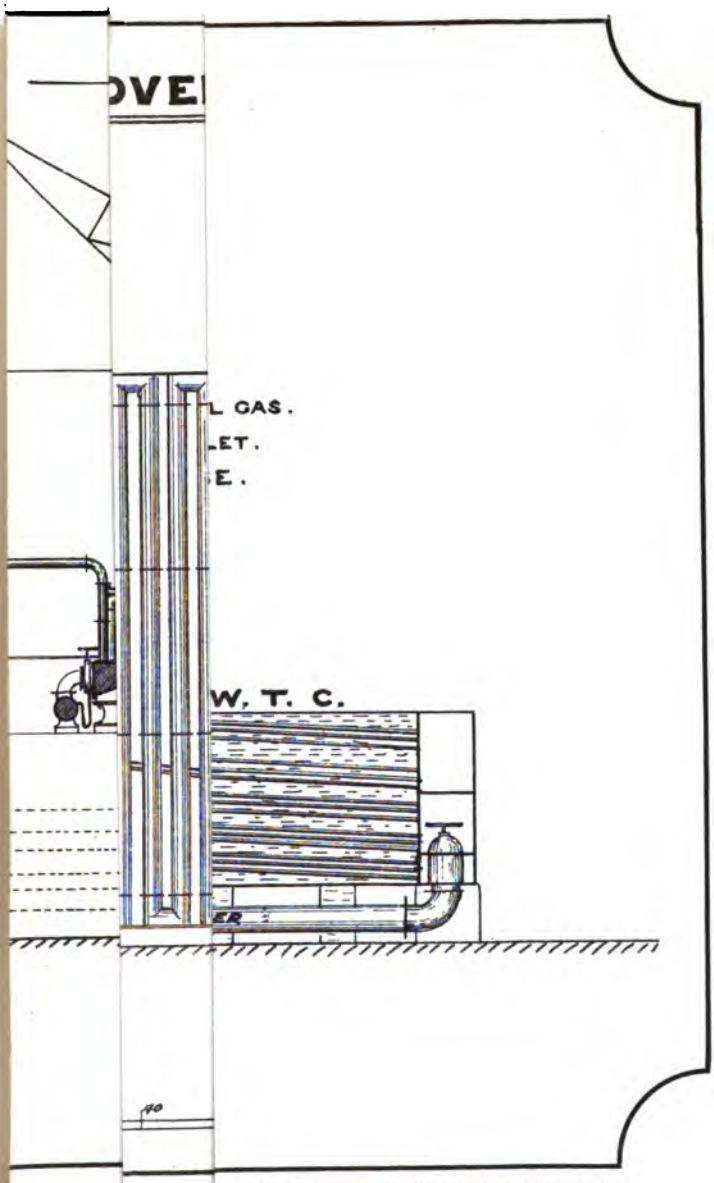
Also—A communication by Watson Smith to the Society of Chemical Industry, London, 1889.

In the paper communicated to the Society of Chemical Industry, 1888, Mr. Lewis T. Wright gives detailed analyses of the tars resulting from the carbonisation of coals at different temperatures. From these analyses it will be seen that tars from low-temperature distillation were perfectly fluid, owing to the freedom from naphthalene, and that they contain a large percentage of hydrocarbons suitable for acting as solvents for naphthalene.

As the temperature of carbonisation rises, however, the character of the tar changes until distillates are yielded, which are almost solid with naphthalene, and containing only a very small percentage which would act as naphthalene solvents, there being practically a gap in the series of distillates yielded as compared with those yielded by tar from the low-temperature distillation. To fill up this gap, and provide sufficient solvents for naphthalene, it would be necessary with the ordinary arrangement of plant to use a large proportion of cannel coal, but this is undesirable for many and obvious reasons.

By the process described in this paper, sufficient solvents are produced by the use of a small percentage of cannel or even by ordinary coal, and from the way in which these solvents are applied their effect is most powerful.

It has already been shown that the remedy can not only be applied without adding to the cost of the manufacture, but that an actual saving is possible over present methods.



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It is hoped that the explanation thus offered of the interesting results obtained will be acceptable to the Members of this Institution, and it is the firm conviction of the Authors that wherever the process is tried, considerable benefit will be experienced.

DISCUSSION.

The PRESIDENT: This is one of those papers which have peculiar interest for us, dealing with new ideas as to how coal and cannel can be carbonised. Although many of you may be of opinion that some of the theoretical explanations given are open to criticism, it is a great step for any one to take to make a practical experiment of this kind, and bring forward the results before us as Messrs. Glover have done. I may tell I have visited Mr. Glover's works at St. Helens to view this process; and I was entirely pleased with the thorough way in which Mr. Glover has carried out this experiment. Mr. Glover calls it an experiment, but it is more than that, for the process has been carried on for four months from last December. Mr. Glover was good enough to show me all the figures of his working. He appeared to have commenced in a tentative way while still using the Peebles oil process, but finding that this method of carbonising enabled him to get better illuminating power he dispensed with the oil; and at the time I visited him he was no longer using the Peebles process, but was producing a better gas, as he has told us to-day, by this method, while using a far smaller percentage of cannel than in earlier days he found necessary. I hope you will discuss this and go into the reasons of this fully.

Mr. A. F. BROWNE (Rotherhithe): It appears to me that the Authors of the paper are to be congratulated on having made a considerable addition to our knowledge as to the best method of employing cannel most economically, and where it is the agent employed for gas enrichment. They claim to get from one ton of cannel the same effect as has been obtained before from two tons. This is a very startling statement; but the result, I understand, is brought about in two ways—first, by carbonising the cannel at a low temperature; and, secondly, by leading the cannel gas away from the influence of the tar

upon the hydrocarbons which it contains during the process of condensation. In those parts of the country where a large percentage of cannel is used, it would appear scarcely possible that this idea of carbonising cannel in special retorts at a special temperature has not been tried before; and I shall be surprised to hear that Messrs. Glover are the first who have done so. Nevertheless, I believe they are the first to have taken the step of freeing it from the deleterious action of the tar. This seems to point to the fact that they are on safe ground in adopting means for the removal of tar from the gas during condensation. But, as the Authors further show, this very fact is likely to bring about an additional quantity of naphthalene in the gas after condensation, because having been less in contact with the tar the naphthalene is not dissolved out. These figures are so surprising that one feels it more than likely that, if such a process were adopted, cannel might, temporarily at all events, be found to be the cheapest enricher; and we should all agree that a cheaper, and a more easily applied method of using cannel could not be suggested. Passing to the question of naphthalene, perhaps many would still hold their judgment in suspense with regard to the theory put forward, though it appears to be a very complete and intelligible one. I am sure the Authors will not feel hurt if I allude to the fact that they are supported in their conclusions by such a high authority as Mr. Young. Nevertheless, I think there are some who are not quite prepared to accept the statement that the only way to get rid of naphthalene troubles is to dissolve the naphthalene out of the gas. Among the older generation of gas managers, it was a desideratum as far as possible to retain the naphthalene vapour in the gas, under the impression that it added to the luminosity. Now we are told that, in order to get rid of the naphthalene nuisance, we must dissolve out the naphthalene. After all, it is a question of £ *s. d.* If these results should be confirmed by other persons at other places, the Authors will deserve well of the gas industry. Still, there do seem to be other means of getting rid of the naphthalene nuisance. Only yesterday I asked a Member if I rightly understood him to say that in introducing water gas he found a marked influence on the naphthalene in his district. He said it was so when using a special brand of oil; but when he changed the oil, the effect was not so good. This seems evidence against the view of Messrs. Glover, that it is useless to

attempt to keep naphthalene in suspension by means of vapours diffused through coal gas or water gas. I should like to call attention to the fact that the point where the cannel gas was introduced in the condensing plant was about that where Mr. Shadbolt for one, and myself for another, have found singular effects to follow the return of coal gas (washed and scrubbed) to the condensing plant, or the introduction of petroleum vapours. Mr. Shadbolt found an increase of luminosity; and in some experiments of my own a few years ago I found that by adding small quantities of hydrocarbons or petroleum vapours at such points, I obtained a remarkable result. I am, therefore, not quite persuaded that the naphthalene is dissolved entirely and deposited from the gas. However, if a cheap and easy method has been discovered of getting rid of the napthalene, I am inclined to think that the value of the naphthalene which could be retained in the gas, as contributing to luminosity, is not nearly so great as the amount of money which could be saved by avoiding nuisance in the district. Therefore, we can do nothing but congratulate the Authors on the good results which have attended their efforts, and wish them every success in a further trial of the system. I believe Mr. Botley is still satisfied with the effect of the addition of oil mist in retaining the naphthalene in gas.

Mr. S. Glover (St. Helens): It may be somewhat unusual, but as Mr. Browne is about to leave I should like to answer the points he has raised. We do not claim to be the first to carbonise cannel at low temperatures or in separate retorts. As a matter of fact, before I had these connections put in I carbonised just the same percentage of cannel in separate retorts, at the same low temperature, and admitted it through the foul main in the same way through the valve attached to the hydraulic main, and got no observable results. What we claim is, that there is not only the carbonising of the cannel at a low temperature, but the manner in which the coal gas is treated before the cannel products are admitted to it. It is that which brings about what Mr. Browne has declared to be wonderful results. I did not expect myself to get such results, and I was only driven to accept them after months of careful investigation. There has been no uncertainty about the results; and there has been no dodging about as to whether it mattered to a few feet where the cannel gas was put in. We have always

obtained from the process, since it was started, certain results; as certain as those obtained during the four-and-a-half or five years we were using oil gas. The results have been as satisfactory as when we were using oil gas.

The PRESIDENT: I do not think Mr. Browne has called your facts into question.

Mr. GLOVER: I only wanted to point out that the results were obtained by simple methods, and with no uncertainty whatever. We admitted to the coal gas a percentage of gas free from naphthalene, and so diluted the naphthalene-charged gas with gas having no naphthalene in it as to carry forward with more certainty the naphthalene still remaining in the coal gas. We do not claim to have washed out of the gas the whole of the naphthalene.

Mr. BROWNE: You do not say that in your paper.

Mr. GLOVER: I know that. I wanted to explain it.

Mr. FOULIS (Glasgow): Will you explain what you mean by a low temperature?

A MEMBER: How much is the make per ton?

The PRESIDENT: 10,290 feet per ton.

Mr. LACEY: Not out of cannel, I presume?

The PRESIDENT: No; out of the mixture.

Mr. BOTLEY (Hastings): A few remarks from me may be of interest, because last year, in conjunction with my son, I had the honour of reading a paper on the question now raised; and although the paper was rather complex, there are certain theories advanced which experience tends to show are likely to be realised in future. Now another year has passed those theories have been amply proved; and I am happy to acknowledge that Messrs. Glover confirm them. There is nothing I take exception to. The only thing I should criticise is the means of arriving at that result. It is a question of time, of the coal you are using, and of the gas you have to supply. Indirectly the question of enrichment comes in, but not very prominently. There is no question that oil gas made by the Peebles process, or by the excellent process of Mr. Foulis at Glasgow, is of great value as an enricher. As has been pointed out, the illuminating value of oil gas is greatly in excess of its real value as an enricher; but with carburetted water gas that is not so. As a rule, if carburetted water gas is made of

high quality, and used for enrichment, so far from getting a high value in many cases there is a loss.

The PRESIDENT: I do not think that is accepted.

Mr. BOTLEY: It is so in many instances; I am speaking of 24 or 25-candle gas, which does not compare in enriching value, when mixed with ordinary 14-candle gas, with oil gas made by the Peebles process. I have proved that by experiment. It may be different in other places where you are using different qualities of coal. With regard to the question which has now been raised at Hastings, we are a 15-candle Company. At St. Helens Mr. Glover is able, with ordinary coal, to get 15½-candle gas. I should be very happy if I could get coal of the same description in the south at a reasonable price.

Mr. GLOVER: That is another of my statements where I went to the utmost against the process. I went to 15½ candles, but I ought to have said 15 candles.

Mr. BOTLEY: The quality of the gas to begin with makes a great deal of difference as to what is required to be added. I am really surprised to think that any difficulty should have been experienced at St. Helens from naphthalene with coal of that high quality, added to which is the use of the Peebles process, which has an effect on the naphthalene in manufacture. But the Peebles oil gas is not a deterrent of naphthalene in distribution. I know several cases in which the process is operated; and the naphthalene trouble is as prominent as where coal and cannel are employed. Now at Hastings I am quite aware that cannel is one of the best solvents of naphthalene. I am satisfied if you could use sufficient cannel you would to a large extent get rid of your difficulties; but if we were to do that it would be necessary to have the illuminating so high as to give the consumers a better quality of gas than they require or is desirable. In connection with this I have bye-passed gas from cannel coal, made in separate retorts, into the foul main, and then into the condenser, for the purpose of clearing it from naphthalene deposits, and we have found during that time a greater enrichment value in the gas. At Hastings we were in this dilemma, that for years we have used the same description of coal. I think for the last twenty years the same two descriptions of Newcastle coal have been in use, and all that time the naphthalene difficulty has been an increasing one. These difficulties went on for a long number of years, until at last we

got into such a position that it was difficult to know how to keep things going with the number of blow outs and so on, and therefore investigations were made. We found that the popular idea that certain hydrocarbon oils would have an effect on the naphthalene was erroneous; and therefore we started the process described a year ago, which was hit on almost accidentally, but the success of which has been undoubted. Last year I was able to give you some results. It was started in 1895, when not only the mains but all the services were stopped up. Therefore for a long time we had to use an excess of oil for misting or fogging the gas; not only to keep the naphthalene in the gas, but to dissolve the naphthalene in the mains and service-pipes. At first we over-saturated the gas so much that at certain positions you could detect faint traces of oil on the fittings. That was done for the purpose I have mentioned. After a time we found we were clearing the whole of the mains and services from naphthalene; therefore we reduced the amount of oil we were using for misting, and only used sufficient to keep the pipes clear. In 1893 our stoppages were 13·55 a day; in 1894, 11·41; and in 1895, 19·52. In this year the process was introduced towards the autumn. The next year, 1896, the stoppages were reduced to 4·55 without any alteration in carbonising or in coal. In 1897 the number was reduced to 2·10 a day; and this year, to date, we have got down to 1·32. There has been a great increase in the gas consumption, so that practically, whereas in 1893 we had a stoppage for each thousand feet of gas sold of 0·0153, in 1897 we only had a stoppage for 0·00209; and whereas in 1893 we had one stoppage throughout the year to every consumer, last year we only had one for every ten consumers. That, of course, is a result which is very satisfactory to us; and 75 per cent. of the stoppages we have had this year are due to other causes than naphthalene. With regard to the remainder, there is an uncertainty about them. The great point is that all this is obtained without any perceptible increase of cost. In fact, the cost of the process at Hastings is so small that it need not be considered. In the first year it cost 2½*d.* per ton for the oil apparatus and everything, and then we were over-saturating the gas; last year it cost 1*d.* per ton; and it now costs 0·228*d.* for every 1000 cubic feet of gas sold. There is one remark made by Mr. Glover which absolutely confirms what I said last year, that the volume of oil misting

required to prevent the deposition of naphthalene is very small. I have pointed out that the quantity of cannel gas introduced into the bulk of coal gas is small, and about equal in proportion to the quantity of oil mist we are using at Hastings for the purpose of maintaining the gas in its normal condition. I may mention one matter in connection with that. It has been said to me, "But you use carburetted water gas at Hastings." But last year, owing to a variety of causes, and making a number of experiments during the whole of the year, the quantity of carburetted water gas was less than 8 per cent. During that time we used Newcastle coal—New Pelton and Pelaw Main—with Curly cannel to the extent of 1·82 per cent. to maintain an illuminating power of 15¾ candles. That being the case, carburetted water gas could have had practically no influence on the question of naphthalene, for it was not in use for eight months of the year. Practically the oil used was one gallon of oil to envelope 166,000 cubic feet of gas, showing what a small volume is required. I would also point out with reference to carburetted water gas, where used largely, and made in the ordinary way, I think it quite possible that the same effect will be produced as by using an oil mist. Carburetted water gas will be found, if examined, to have an oily humidity, whereas coal gas has a watery humidity; and therefore the one prevents the other from depositing the naphthalene. I have been making tests with regard to the humidity in carburetted water gas, and in spite of every precaution there is still a humidity after it has gone through all the processes of washing and purification, and has gone into distribution. That may be accounted for by the way in which it is made. A quantity is rushed through the condenser in such a condition that there is not sufficient time contact. We learn regarding this question of naphthalene that in other places in the south using similar coal to myself the naphthalene trouble is unknown. All I can say is, if when using Newcastle coal they are able to avoid naphthalene troubles altogether, they are extremely lucky.

Mr. J. W. Helps: I should like to congratulate Messrs. Glover upon the very interesting paper they have brought forward to-day. I do not know that I need attempt to criticise the paper, except to make one remark as to the cost. I asked Mr. Glover this morning whether he had made any calculation

as to the actual cost of enrichment of his gas, as he is now doing it, compared with the Peebles process; and he told me it came out cheaper now than it formerly did. He tells us in his paper, that he is able to get gas of 18½-candle power with the use of one-half the cannel he formerly used. I find it costs me about 1¾*d.* per candle per thousand feet to enrich with cannel; and if I was able to reduce the quantity by half, it would then cost me something like seven-eighths of a penny. At present we are enriching our coal gas with water gas, and I feel pretty confident it is not costing us anything like that. Mr. Botley has been making an interesting statement as to the effect on naphthalene deposits of the process in operation at Hastings; and he said there are some places in the south where it is claimed by the use of water gas, using almost exactly the same coal as at Hastings, it is possible to do away with naphthalene, and probably he refers to Croydon as one of those places.

Mr. Botley: I did not do so; I spoke of places where they do not use carburetted water gas.

Mr. Helps: Mr. Botley has given a number of figures of complaints of stoppages. Now I do not suppose there is any subject upon which there is such a diversity of opinion as that of naphthalene. I can only say, during the five months we have been using water gas we have been practically free from stoppages due to naphthalene. One point of interest is to be found in the fact that prior to the use of water gas our photometer at the gas-works and the one at the testing station two miles away gave very similar results, that is to say, that when it was 15·5 candles at the works it was 15·3 candles, or something like that, at the Katharine Street station. Now, during the last few months we have been getting results at the Katharine Street station, on an average half a candle higher than at the works where the gas is made. Naturally, any one would think it would be accounted for by the fact that the gas enriched by the water gas was able to take up old deposits of naphthalene in the mains, and carry them on, and that the testing benefited from the presence of the naphthalene. But it is always unwise to make statements after a short experiment; and I must confess that the day before I came away my chief inspector told me that he had that morning received several complaints of naphthalene stoppages. Perhaps, there-

fore, if I had spoken a week ago I might have been stronger on the point; but it does appear to me that, now we are getting into what some people call summer weather, we get more complaints than in the winter time. It seems to me that, from Mr. Botley's point of view, it is a great pity we have not recently experienced those changes in temperature during the winter that we had some three or four years ago. I do not think his system has had a fair trial; and I want to draw attention specially to the fact that I have been able, practically, by the use of carburetted water gas, to do away with naphthalene deposits. I do not say the naphthalene is picked up by the water gas or is prevented from being deposited. How to explain it I do not know; but we have been using the same coal as Mr. Botley uses, and supplying gas of from 15½ to 16 candles.

Mr. Botley: I should like to ask Mr. Glover what proportion of common coal gas it would be necessary to bye-pass in order to bring up the gas to the quality he says he can get without cannel. I understood him to say that, where the illuminating power does not need to be too high if you bye-passed the gas distilled at a low temperature from common coal, sufficient enrichment would be obtained without anything else. With regard to Mr. Helps' remark as to variations of temperature, the diagram now published shows that during 1895 the temperature went down 12°, and there was as much variation as in any previous years.

Mr. T. Holgate (Halifax): I have not had the privilege of reading the detailed statement which is referred to in the paper as to the quality and volume of the gas produced in connection with these experiments; but it appears to me that if we had the volume of the gas, the illuminating power, and the nature and quality of the tar products when this cannel was distilled at the high and low temperatures, we should have some valuable information. Mr. S. Glover gave us the information that where Young's oil gas was used he is still troubled with naphthalene deposits in the services. Speaking from memory I believe the gas made by the Peebles process is almost free from benzol and benzene analogues; the illuminating power being due almost entirely to ethylene. In the case of water gas there is usually present a small quantity of benzol which may account for the solvent action on naphthalene.

I quite appreciate the remarks which Mr. Browne made at the opening of the discussion when he so clearly placed the process in its true light. It appears to me that the Authors have the means in their hands of testing how much of this improvement is due to the low temperature carbonisation, and how much is due to the point of admixture at the outlet of the condenser. If they could pursue their investigations in this direction the Members of the Institution would be very pleased to hear the result.

Mr. E. A. HARMAN (Huddersfield): I am almost surprised this paper has not been entitled another cure for naphthalene. This ever-recurring subject is certainly a most attractive and practical one. Messrs. Botley gave us a paper at the last meeting upon it, while Messrs. Glover have given us a most interesting one to-day. We have in Huddersfield a system of low heat carbonisation with Scotch oil, which has the same object. We have therefore a large quantity of information how to prevent naphthalene. But in spite of this accumulation of knowledge, stoppages from naphthalene still frequently occur, and will continue to occur for some time. It is only by experiment and such papers as these, and a careful consideration of them that we shall be able to arrive at a satisfactory solution of the difficulty. One of the chief points in the present paper, from the practical point of view, seems to be the question of the separation of the tar at the hydraulic main. Formerly it was usually allowed to flow with the gas down the foul gas main almost as far as the condenser. In many modern gas-works the tar is now taken off at the hydraulic main by a system of overflows and runs away in pipes quite distinct from the gas itself. I believe the nuisance could be traced in some works to the date when the old system of tar drainage was superseded by a system of adjustable tar and liquor overflows having baffle plates which compel the tar to flow away before the liquor. My own opinion with regard to naphthalene stoppages, having tried several experiments, is that the climatic conditions are chiefly responsible—principally very warm days followed by very cold nights. One year we may go without many stoppages straight through; and if we had only been fortunate enough at the commencement to have started some little fancy process we are ready at the end of the year to patent it; but unfortunately as soon as one starts some experiments the naphthalene nuisance recommences.

Mr. BROADBERRY (Tottenham): I had not any intention to join in this discussion and am not prepared with figures, but Mr. Browne made a reference to a question he put to me about naphthalene troubles after we went in for water gas. I told him at the time we commenced with water gas we were having considerable trouble from naphthalene; and immediately we commenced to supply water gas, using about 35 per cent., it practically ceased. It first dropped for two days to about 5 per cent. of the complaints we previously had, and gradually disappeared altogether. Since then we have occasionally had troubles—slight troubles—from naphthalene, but we have found they do not coincide so much with the variations of the atmosphere as with variations in the temperature of the checker-work due to searching for better oil results. If we get our temperature too high in the checker-work we find we get troubles from naphthalene. This points to the correctness of the claim made by Mr. Glover with regard to low-temperature distillation. At Tottenham we have not been in the happy position of Mr. Helps of getting better results at the distant testing stations; but we have found there is considerably less falling off in the illuminating power at the Wood Green station than there was before we started carburetted water gas.

Mr. CROSS: I was surprised to hear from Mr. Browne that stoppages in certain districts where they use water gas are more frequent now than they were some years ago. But that view has been somewhat modified since. Mr. Helps expresses a doubt as to whether he is going to have more stoppages; and Mr. Broadberry says the stoppages he has observed depend on the heat of the checker-work in the carburetter and superheater. My own experience of water gas extends over a period of nearly two years. When we started using it we passed the carburetted water gas into the coal gas apparatus at the inlet of the exhauster. We dropped all trouble with naphthalene on the works, but in the district we had a surprising increase in the number of stoppages. We got over that in course of time, and now we are practically free. I agree with Mr. Botley that the stoppages we get now are not altogether due to naphthalene. Just before Christmas I finished a new apparatus, by which we pass all the water gas direct from the plant, and effect the mixture with the coal gas at the inlet of the holder. I shortly afterwards found naphthalene on the works. I have not had

much trouble from it; if I do have trouble from it I shall revert to the old state of things and pass my water gas through the exhausters. As Mr. Helps mentions, we have not had any severe weather for the last couple of years or so. It is my intention when we get severe weather in the future to immediately put in more oil and raise the quality of my gas, so as to make it act as a carrier for naphthalene.

Mr. W. FOULIS: I think the question of what is meant by low temperature is really at the bottom of the whole thing—if the coal is carbonised at a temperature which yields the best results. There can be no doubt that if you distil cannel at a low temperature, or rather, I should say at a suitable temperature, you will get a gas which will certainly have a higher enriching value than if it is distilled at a higher temperature. The statement of Mr. Glover, that he is able now to produce a 19-candle gas at 7*d.* per 1000 feet, is certainly an excellent result, and we would all like to be able to do that, but until we have more information with reference to the temperatures it is difficult to discuss the paper at all. I find that unless the temperatures are kept within a comparatively small range in the manufacture of our enriching gas, we cannot get the value that we would otherwise get, but by keeping the temperature within this radius we get a very much higher enriching value than is shown by photometric tests. At the present time we are enriching 5,000,000 cubic feet of gas per day to the extent of three candles, with no more than 2000 gallons of oil.

The PRESIDENT: I think we have had a most interesting discussion, though it has been more on the naphthalene question than any other. I hope the interest which the paper has evoked will be gratifying to Messrs. Glover. One of the important points in the arrangement of this plant, which evidently must have a very strong influence on the results obtained, has been somewhat lost sight of in the discussion, viz. the temperature of the cannel gas at the point at which it mixes with the coal gas. The temperature is kept up by a steam pipe; the cannel gas is conducted by a 6-inch pipe, 250 feet long, falling all the way from the hydraulic main; and its temperature is raised to such an extent that where the gas enters the outlet of the condenser the cannel gas was still at 120°. The gas with which it was mixed was condensed to 60° or something less. There is an open syphon fixed at the end of the pipe; and deposits of liquid are falling from that almost wholly com-

posed of condensed water, though there was a little oily matter on the surface. To my mind this is the interesting feature of the thing. Here you have a certain quantity of gas produced from cannel at a moderate temperature—not very low—and evidently very heavily charged with hydrocarbon vapours. The temperature is kept up until it is suddenly introduced into a large volume of thin gas which has already had all its tarry matter condensed out of it, and with that probably all the naphthalene that it could no longer carry. That raises the temperature of the gas by about 9°. That seems to me an interesting feature of the apparatus, and very suggestive as regards the capability of the gas to sustain these hydrocarbon vapours when introduced to it in such a manner. With regard to naphthalene, that is a very difficult question, but there are one or two points about it which it is well to bear in mind. One is, that naphthalene does not appear to be deposited so long as the gas contains any vapours in a state of mist, or the point of being themselves liquefied. As long as you find liquids in the main you do not find naphthalene; it is only found where they are dry. Well, now, does not that show that any system of enriching gas—or "fogging" it, as Mr. Botley calls it—which gives that gas an oleaginous vapour to carry along with it, will prevent stoppages by naphthalene? It may result from such a process as this, or by such a process as Mr. Botley introduced to us, or it may result from a mixture of water gas, in which all the hydrocarbons are not thoroughly fixed. With the Peebles oil gas it does not result, for the simple reason that it is a truly permanent gas and nothing is deposited from it. I am not sure as to whether I misunderstood Mr. Botley in regard to water gas. I understood him to say that the enriching value of carburetted water gas is less than its illuminating value.

Mr. Botley: It is about the same; whereas, the Peebles oil gas being a permanent gas, has a higher enriching value.

Mr. S. Glover: We can only feel very well satisfied with the tone of the discussion. What we want to clearly explain is this—and we want to emphasise the point—that gas depends for its illuminating power upon its composition. Perhaps that is a fact which has not been sufficiently realised by gas engineers yet. It depends upon its composition as to what is its illuminating power, and it depends for its composition upon

how the coals from which it is produced are dealt with. By this process we claim to do very much more than Mr. Foulis has mentioned. It is not simply carbonising coal at a low temperature—in fact, we do not like the phrase "low temperature" so well as the words Mr. Foulis has suggested—"a suitable temperature." But the process does not consist simply in carbonising the cannel at a different temperature, but the way in which the whole of the products from the cannel are dealt with—and not merely the gas. The heavy tar is left behind; our take-off pipe rising from the top of the hydraulic main; and the lighter and valuable hydrocarbons are carried forward along with the cannel gas in the special pipe, and are kept hot by means of the steam pipe, until they are presented to the coal gas which has been denuded of its tar, and the coal gas then carries them forward. Therefore, we have valuable hydrocarbons specially prepared, which are valuable for enriching and also for treating naphthalene, and presented to a medium which is also the very best that could be provided for developing the illuminating power of the hydrocarbons. With regard to the question as to the use of coal instead of cannel for this process, we have not any well ascertained facts; but our idea is that from seven to eight per cent. of coal would be required to raise the illuminating power one candle, and that by heating coal in the same way as cannel, not only would an enriching gas be obtained, but also some of the same solvents of naphthalene which are so valuable. We have had a good deal of evidence this afternoon as to the various effects of mixing water gas with coal gas; and that is the case no doubt because of the varying temperatures to which the oil in the water gas process is submitted in a water gas plant. In some part of the process, or perhaps all through the process, some of the oil is cracked up at too high a temperature; while some of it may not be cracked up sufficiently. Therefore, you have uncertain results. With this process we claim that you have reliable results, because you have the thing under proper control. There is no doubt, as Mr. Broadberry said, a great deal of the advantage is obtained by the lower temperature at which we treat the cannel, so as to give us richer hydrocarbons. I cannot say what effect water gas would have upon coal gas. With regard to the effect of Peebles oil gas on naphthalene, there is no doubt that so far as it is mixed it acts as a preventive,

inasmuch as the oil gas has no naphthalene in it at all. But the quantity required for enriching is so small that it has little opportunity of preventing the formation of naphthalene. With regard to the cost of cannel, where cannel is too expensive, I would recommend the use of coal. That is in answer to Mr. Helps' question.

Mr. T. GLOVER: There is only one point I need refer to. There is a very considerable gain in sperm value by using cannel in this way, compared with allowing the gas to mix in the foul main. The gain in sperm value would be 50 lbs. per ton of coal.

WASHERS AND SCRUBBERS.

By EDWARD A. HARMAN.

The subject may be considered as divided between chemistry and engineering. In order to rightly appreciate the functions and duties of washers and scrubbers, it is desirable to review the conditions under which gas is liberated in its distillation from coal.

Coal is the remains of vegetable matter (wood fibre, &c.), composed of carbon, oxygen, hydrogen, nitrogen, &c., which has been submerged in water by land-changes time after time. Thus it was covered with muds and detritus flooded down from adjoining lands, and saturated with mineral matter in solution. This is evidenced in the small veins of coal, the interstices of which are filled with finely-divided soluble substances. In coal distillation, therefore, the gases given off do not correspond entirely to those obtained from wood, but consist also of considerable quantities of others. The decomposition by heat liberates sulphur, which at high temperature combines with the hydrogen and carbon given off to produce sulphuretted hydrogen and carbon bisulphide. In addition to these, the nitrogen combines with the hydrogen given off to form ammonia, whilst the carbon and hydrogen chemically combined in the coal are liberated as hydrocarbon gases. The vapours are all condensable, as, indeed, are all the gases under certain conditions; but it is the wide difference in their condensing points which enables the surplus hydrogen, marsh and olefiant gases, to pass unarrested through the processes in use for the extraction of impurities. To appreciate the changes which take place in the distillation, an analysis of the gas, after it has deposited a large quantity of its vapours in the hydraulic main, cooling mains and condensers, will suffice. The composition of the gas at the outlet of the condenser, for the

purposes of consideration, may be approximately taken as follows:—

	Grains per 100 cubic feet.	Per cent. by Volume.
Tar	some vapours	
Ammonia	220	·70
Sulphuretted hydrogen	950	1·50
Carbon dioxide	1640	2·00
Carbon monoxide	2600	5·00
Carbon bisulphide, other sulphur compounds, and cyanogen	70	·05
Oxygen	trace	
Hydrogen	1850	50·00
Nitrogen	2000	4·00
Marsh, olefiant, and other gases		36·75
Total		100·00

The question therefore is, which gases require retaining and which eliminating, and the best method available for accomplishing this end.

Hydrogen burns with a non-luminous but intensely hot flame, and the products of combustion are imperceptible. It is very slightly soluble in water, 100 cubic centimetres dissolving about 2 cubic centimetres of the gas. Hydrogen forms about 11 per cent. of the weight of water and 25 per cent. of the weight of marsh gas. It is moreover an essential element in the extensive class of bodies termed acids.

Marsh gas or methane, carbon monoxide, and gaseous hydrocarbons, when burnt do not have a deleterious effect.

Carbon dioxide, nitrogen and ammonia detract seriously from the illuminating power of the gas, inasmuch as they require to be heated to the temperature of the burning gases, and abstract proportionately from the heat of combustion of the others.

Sulphuretted hydrogen and carbon bisulphide burn with a pale blue flame, the irritating fumes and vapour therefrom having very injurious effects.

The objectionable gases for removal are carbon dioxide, ammonia, sulphuretted hydrogen, and other sulphur compounds. These gases are soluble in water approximately as follows.

One volume of water at 60° F. absorbs—

700 volumes of ammonia.
3¼ volumes of sulphuretted hydrogen.
1 volume of carbonic acid.

It is well known that the solubility of gases decreases rapidly with an increased temperature of the liquid to which they are exposed.

Carbon bisulphide is insoluble in water. Ammonia, being a very strongly alkaline body, is capable of neutralising acids, whilst carbon dioxide and sulphuretted hydrogen are acid bodies. These will under suitable conditions combine—that is, the acids with the alkali—to produce salts. Similarly, sulphuric acid absorbs ammonia, as illustrated in a sulphate of ammonia plant, with the exception—that whereas sulphuric acid as a strong acid possesses great affinity for such powerful alkaline bodies as ammonia, the others, carbonic and sulphidric acids, are only very weak ones, so much so that they only exhibit acidic properties when in solution, and then but very faintly. Their combinations with ammonia under the most suitable conditions only produce unstable salts, which break up slowly at ordinary temperatures into their constituents, and at higher temperatures very rapidly. One of these salts, ammonium carbonate, is used in the estimation of the sulphur in the gas in the Referee's Test, as it gives off a portion of ammonia at the ordinary temperature to the products of the combustion of the gas. If these bodies could be combined to saturate each other and produce salts, they would be removed from the gas to the extent of the whole of the ammonia, and half the volume of carbonic acid or sulphuretted hydrogen.

The properties already mentioned suggest at once a means of freeing the gas from impurities, namely, either dissolving out with water, or combining the alkali and acid bodies and producing salts. The readiest means available, taking into account their solubilities, is to wash the gases. From the great solubility of ammonia in water, it might be conceived its removal would be a most simple matter, but in actual practice it is not so easy as it appears. It only exists in the gases to a very trifling amount when compared with the volume. For the purpose of comparison consider it to be about 7 in 1000 by volume. One ton of coal yielding 10,000 cubic feet, therefore contains about 70 cubic feet of ammonia, and would only require theoretically one-tenth of a cubic foot of water, or about five pints, to dissolve it. In actual working this is far from sufficient. The water is never thoroughly saturated, and, moreover, the solubility takes place directly in proportion to

the pressure of the contained gases. If ammonia gas was confined alone in a vessel at 30 inches of mercury, or at ordinary atmospheric pressure, it would be absorbed to the extent of 700 times the volume of water in the vessel, whereas ammonia existing in the proportion of ·7 of its volume as a gas, will only exert a pressure of 7 thousandths of an atmosphere or ·21 inches of mercury, at which pressure very little ammonia is dissolved per volume of water, on account of the small partial pressure of the gas, although it is able to retain it when dissolved, because the water is at atmospheric pressure; therefore the successful abstraction depends upon the time contact between the gases and the water. It is this which has suggested the desirability of a washer being worked under pressure.

Carbonic acid and sulphuretted hydrogen are affected similarly, so that to remove these, could the solubility of them saturate the water used, a great deal of plunging and agitating of the water would be necessary to effectively remove them. Indeed, it is this object which has been aimed at in purifying machines, concerning which more will be considered. Other considerations have also to be taken into account, namely, the instability of ammonia, carbonic and sulphidric salts. Their instability is augmented, as that of the solubility of the ammonia, by the temperature. Whereas at ordinary temperatures the before-mentioned solubilities were obtained, a variation of a few degrees interferes seriously with the result, as shown by the following table.

One volume of water absorbs—

Temperature Fahrenheit.	Carbon Dioxide.		Sulphuretted Hydrogen.		Ammonia.	
		Loss per cent.		Loss per cent.		Loss per cent.
60°	1·002	..	3·23	..	700	..
62°	·973	2·9	3·16	2·1		
64°	·938	6·3	3·03	6·2		
68°	·904	9·7	2·90	10·2		
176°	..	..	..	..	200	71

The effect of temperature upon the deposition of ammoniacal salts, particularly in the case of sulphidric and carbonates, is very clearly and decisively shown in the composition of the

liquor obtained from the hydraulic main, where the temperatures vary from say 140° to 180° F. The hydraulic main liquor contains only about one-sixteenth of the proportion of the sulphides and carbonates deposited in the condenser, whilst such salts as sulphates, sulpho-cyanides, &c., are almost wholly left in the hydraulic main liquor. The liquor contains also far less free ammonia than other parts of the washing and scrubbing plants. The fixed ammonia from the hydraulic liquor is approximately 50 per cent. of the total ammonia in it. As the temperature lowers, the sulphides and carbonates of ammonia tend to form very soluble salts, which become dissolved in the aqueous vapour of the condenser, and are found there in the largest quantity. The alkaline and acid bodies contained do not combine to saturate each other to the full limit, since, being only a small proportion of the gas, their pressures are too attenuated. These salts, too, dissociate rapidly at ordinary temperatures. This phenomenon is well known.

Limestone heated in a closed vessel parts with carbon dioxide until the gas liberated exerts a particular pressure. If this gas be pumped off, a further dissociation of limestone occurs, until the further carbon dioxide exerts the pressure at which dissociation ceases. This would continue if the carbon dioxide were pumped off as formed until the limestone was completely decomposed. The inverse would occur by lowering the temperature or by increasing the pressure. Thus it is with the carbonic and sulphidric salts. Their partial pressures in the gas are such as to almost prevent any mutual attraction they might exert, and be dissociated as quickly as formed. Consequently they do not form, or probably only to a very slight extent. The tendency would be enhanced by washing with alkaline solutions such as gas liquors.

It is therefore most important to reduce the temperature of the gas. The escape of ammonia from the scrubbing process during the summer and warmer months is sufficient proof of the dissociating influences of heat, and its influence in effective washing. Sudden cooling is apt to condense the valuable vapours out, and must be avoided.

The quantity of water desirable is a question for careful calculation. Ammoniacal liquor has value as a commercial product, which is dependent upon its strength, and has to be considered. In addition, the washing of the gas by too much

agitation with fresh water dissolves and precipitates some of the illuminating constituents. It is consequently desirable to wash the gas with solutions which have previously been partially saturated up to almost saturation point. The quantity of liquor deposited in the hydraulic mains and condensers equals about 50 to 60 per cent. of the total liquor obtainable. This liquor is used for first washing, because it is to some extent saturated with gas, while it is not strong enough to work up profitably in the sulphate plants. The quantity of this liquor is more than sufficient to absorb all the ammonia existing in the gas. The last washing has to be done by clean water, of which about 10 gallons per ton of coal has generally been found sufficient. The reason weak liquor does not effectually remove the whole of the ammonia is because of the before-mentioned dissociability of alkaline sulphides and liquors, the vapours of which are given off appreciably at all temperatures, thus necessitating the application of clean water for the finishing operation. The best method for washing operations is a matter of great difference of opinion. Water to take ammonia into solution must be brought into actual contact with it before union can be effected. This contact is made by causing the gas to rub against the surface of the water, and may be accomplished by various methods. It may be brought into contact by allowing it to traverse a column down which is falling a continuous shower of water like rain or spray; or it may pass over a large wetted surface, or it may be agitated in water and forced into small bubbles. It has been pointed out that the effectual removal of the ammonia depends upon the time contact. Suppose water to be distributed down a tower or scrubber passing three millions of cubic feet of gas per diem, at a rate of one volume of water to every thousand cubic feet of gas passed, or nearly at 13 gallons per minute—say, approximately, two cubic feet. Consider the water to be divided into drops of $\frac{1}{4}$-inch diameter, the contents of which equal ·00818 cubic inch. Then the number of drops represented by this quantity would be two cubic feet divided by this amount, which equals 422,494 drops. The surface presented to them would be 576 superficial feet area ($\pi a^2 \times 422{,}494$), and they would be in contact with the gas the time taken to fall down the tower. This surface area would be increased by dividing the drops finer, as by a spray distributor. The mechanical power required to obtain

minute distribution is in excess of the relative value of the finely-divided spray over a simple system of drops.

In dividing the gas into bubbles a very different case is presented. It is far easier to subdivide the gas into anything chosen than to subdivide water. All that is required is to keep the liquid well agitated and let the gas issue into it. Washers are based on this well-known principle of compelling the gas in a finely-divided form to pass through a liquid instead of merely over a surface.

In purification experience has an important part; for, while the laboratory results form an admirable comparative guide, there are forces which come into operation upon the manufacturing scale, when treating millions of cubic feet, that are not apparent when experimenting with a fractional part. It is to the most desirable designs of apparatus for effecting purification that attention and experience is invited.

The washer is one of the earliest forms of apparatus for extracting ammonia and tar. It was frequently used without due regard to its limitations, as to materially reduce the illuminating power of the gas, and it was probably this, coupled with the heavy back pressure of some of the old designs, which retarded its extension. Indeed, the back pressure alone was sufficient to discredit any apparatus. It is, or should be, always used either in connection with a scrubber or scrubber-washer, and always before them. The primary idea of the washer was very good, namely, that of extracting the tar and a large percentage of the ammonia. As stated, the reason the washer does not remove every trace of ammonia, is that it cannot be kept charged with clean water, as the gas converts the water into ammoniacal liquor, and the last contact of the gas is therefore with liquor instead of clean water.

In 1891 an admirable paper * upon the efficiency of washers was given by Dr. Bueb, Chemist to the German Continental Gas Company, in which he stated that at the Elberfeld Gas-works the separation of ammonia was effected throughout half the works by means of washers.

Temperatures.—Both washing and scrubbing could be effected better if a complete control were obtained of the temperatures of the gas at all portions of the apparatus. It is with this object in view that the condensers abroad are generally

* Vide 'Journal of Gas Lighting,' vol. lviii. p. 576.

placed in closed houses. Where washers are placed in the open air, the liquor therein frequently falls below 60° Fahr., with serious reduction of the heavy hydrocarbons. It is therefore desirable to have the washing apparatus enclosed.

Tar Extraction.—In the United Kingdom the common practice is to extract whatever tar is left in the gas after condensation at the washers and scrubbers; which has, however, the objectionable point of rendering these portions of the purifying plant less efficient for their particular work. Upon the Continent preference is given to the extraction of tar by means of tar extractors, such as those of MM. Pelouze and Andouins. It is true this has been adopted in some few works at home, as well as other systems of tar extraction. The separate operation for mechanically extracting the precipitated tar or floating particles is a debatable question. The object of many gas engineers is to condense out the tar, which, of course, necessitates large condensers, certainly larger than would be required if the tar were previously extracted. Even with large condensers it is impossible to condense out all the tar at atmospheric temperatures. Many engineers prefer the gas remaining in contact with the tar as long as possible. It is questionable whether it is desirable to bring down the temperature of the gas to 60° before washing, the object of doing so being principally to reduce the quantity of tar in the gas.

Scrubbers.—The form of tower scrubber most familiar is, perhaps, the Mann and Walker type, as illustrated in Drawing No. 1. It consists of a cylindical tower, the height being about three to five diameters. A machinery room adds finish and ornament to the top. In the upper portion of the vessel is a brushwood wheel, which receives a supply of clean water from revolving water distributors, ingeniously designed to work eccentrically, so that in traversing the outer circumference of the vessel they travel slowly, but when nearing the centre, rapidly. The gearing is worked by bevel wheels from a vertical shaft, supported from the sides of the vessel. The contained material generally is either coke or boards on edge, although other material is also used. The channelling of the gas and water through coke makes boards preferable. The material is supported on a series of cast-iron grids, leaving each tier distinct and separate for the dispersion and diffusion of the gas. The gas enters at the base, meeting the strongest and warmest

liquid, and passes from tier to tier vertically to the top of the vessel, where it descends an outlet pipe placed in the centre. The water entering at the top in the form of finely-divided spray descends through the material, and the gas being forced through the separate tiers gets well brought into contact with the moisture and sharp edges. Mr. William Mann, formerly Engineer to the City of London Gas Company, and Mr. William T. Walker, with whom the Author has had several conversations upon the subject, strongly recommended the gas always to be passed through the scrubber under pressure, instead of exhausted. The gas yields its ammonia to the water, the tar is mechanically arrested by the coke, and drains to the bottom of the vessel, the base of which is generally designed to permit the tar and liquor draining to the outlet pipe leading to the stores well. Where a series of tower scrubbers are used, weak ammoniacal liquor is pumped into all, except the last or finishing one, in which clean water is employed. The ammoniacal liquor when treated in this manner becomes a valuable purifying agent, and is also itself much enhanced in value. One advantage of using liquor is, that the hydrocarbons are not deposited as when water only is used. When scrubbers are used in the dry state, that is, without a liquor or water supply of any kind, the material necessarily extracts or retains the tar only.

Tower scrubbers require cleaning out about once in every eight to ten years. They may be partially cleaned at intervals by steaming, always taking care to commence the steaming process at the top, and following down tier after tier, so as to allow the condensed water and liberated tar to drain downwards, leaving the upper tiers cleaned. As regards the most desirable material for use in scrubbers, Mr. Livesey (to whom belongs the credit of introducing boards) gives the following relative area of wetted surfaces:—

Coke	8½	square feet	per cubic foot
Drain pipes 2 inches diameter ..	21	"	"
Drain pipes 3 inches diameter ..	17	"	"
Boards	31	"	"

It will be seen that, apart from other desirable recommendations, boards present between three and four times the area of coke material.

In a tower scrubber, filled with grids of ⅜-inch by 9-inch

boards, with $\frac{3}{8}$-inch distance pieces, a very large surface is exposed for wetting, and consequent frictional surface-action on the gas. In a tower designed for passing 3,000,000 cubic feet of gas per day of twenty-four hours, say 15 feet diameter by 60 feet high, having six tiers of grids, the surface equals 268,000 square feet. These grids occupy 40 per cent. of the cubical capacity of the tower. In the tower there is approximately 10,602 cubic feet, less 4356 cubic feet filled with material, leaving in the interstices some 6246 cubic feet. The inside of the scrubber, together with the surface area of the grids, presents 270,820 square feet. The gas passes at 34 feet per second, and will be in the interstices of the material such a time as it takes to fill up the 6246 cubic feet divided by 34, which equals nearly three minutes. Multiplying the surface, 268,000 square feet, by the time, three minutes, 804,000 square feet is obtained, which is the value of contact with the gas passing. The result may be written $\frac{\text{total surface}}{\text{volume of gas}}$, which expresses the amount of contact surface available for each volume of gas. The capacity of any washing machine may be gauged from this rule, independent of design. Again, gas, as has been referred to, may readily be reduced to bubbles of a very small diameter, and by this means the contact surface can be obtained equal to any other. Suppose the gas is divided into bubbles of $\frac{1}{4}$ inch diameter. Then for each foot of gas we obtain about 288 square feet of surface area. As gas rises through one foot of liquor in about one second, for this to equal the capacity of the tower scrubber described, it would have to pass through a column of liquid 27 feet deep. The expenditure of power to effect this would be very much in excess of the force required to deliver 13 gallons of water to the top of the tower.

The late Mr. Wyatt * recommended 100 cubic feet of internal capacity of the vessels, with a gas contact of from 15 to 27 minutes for maximum and average makes, and stated that $12\frac{1}{2}$ to 15 per cent. of this volume could be utilised by introducing a washer into the base of the scrubber. The volume of gas contained in the scrubbers at one time amounts to about 1 per cent. of the maximum make per diem. The horizontal nett area of all the scrubbers recommended by Mr. Wyatt is

* Vide 'Journal of Gas Lighting,' Oct. 11th, 1897, vol. l. p. 662.

equal to two superficial feet per ton per diem on the maximum make.

Dr. Ferdinand Hurter's paper * upon Coke Towers and similar apparatus, in 1893, is a valuable contribution to the subject.

Water Distributors.—It is difficult to ensure thorough distribution over all the whole area of a large scrubber, although accomplished at the first tier; the liquid collects and drains in channels through the remainder. The Author has tried steam jets in each tier, with good effect as to saturating the material all over, but the increased temperature of the gas prohibits its use. The Barker's Mill arrangement is perhaps one of the best forms. Gurney's jet consists of a sliding tube with a nozzle, having a fine hole one sixty-fourth of an inch in diameter. The liquid is forced through this at considerable pressure, causing it to impinge against a circular glass disc. Green's water distributor, Goldsmith's, and many others, might be cited.

Washers.—Washers are of numerous designs. The gas passes through a series of perforated plates, brushes, bundles of grids, and many other devices placed in chambers, and being constantly wetted. The surface of these, and the contact, are enormously increased in many cases by constant revolution, and possess advantages, inasmuch as the liquor is retained without pumping, being gradually run off as the strength increases. The gas leaves behind the larger portion of its ammonia in the chamber. The liquor, being retained, is consequently worked up to a far higher degree of saturation. An analysis of the liquor from one of these washers shows the action of the gas clearly. In the first chamber a little fixed ammonia is obtained, while free ammonia, or that held in solution with such weak acids as carbon dioxide, will seem to have displaced the sulphuretted hydrogen, it being found there in the proportion of 70 per cent., compared with the sulphuretted hydrogen similarly held. In the latter chambers the sulphuretted hydrogen seems to enter more into solution. In the last chamber it is side by side with the carbon dioxide, and is found up to 50 per cent. The acid equivalents throughout the series get gradually less. The proportion of carbonic acid and sulphuretted hydrogen in the liquor, and the proportion they bear in relation to each other, vary, principally owing to the strength of the liquor, and

* Vide 'Journal of the Society of Chemical Industry,' vol. xii. p. 227.

partly under the circumstances of formation. Generally between 50 to 70 equivalents of alkaline ammonia is combined with 50 to 70 equivalents of the acids, carbon dioxide and sulphuretted hydrogen, the sulphuretted hydrogen of which forms nearly 20 per cent. The strong liquors contain less than the weaker ones.

The operations of washing remove two or three grains of carbon bisulphide per 100 feet, and the illuminating power is slightly diminished.

It has been shown why the alkaline and acid bodies do not combine to eradicate themselves, on account of their non-affinity at the partial pressures in which they exist in the gas. It has also been shown why the water compared with the solubility is insufficient to eliminate the ammonia. When the pressure becomes more attenuated, then the forces between the dissociability of the weak solution more nearly approximate equilibrium, a rise in temperature effecting the liberation of a small quantity, or a corresponding lowering effecting the absorption. The relative capacities of washing the gas by rain vapour; material spread surface contact; breaking the gas into bubbles, and by the presentation of new surface area to the action of the gas in the various forms of mechanically worked washers, have been pointed out. Rain and vapour is of little practical use, the mechanical force necessary to present it in this form being far from the advantage derived from washing the gas by breaking it into bubbles. The mechanical force necessary to break the gas into bubbles, simple as it appears, is greater, while the surface thus obtained is less, than required for passing the gas through tower vessels with large surface area. Even these are behind mechanical washers of various kinds, as their surface contact can be regulated, and is also enhanced by utilising strong liquors for the crude gases. While considering the surface contact, it may be mentioned that a limit may be obtained in the fineness of the layers presented to the surface, insomuch as the material required to do this occupies a greater portion of the cubic area of the tower or machine, thus accelerating the flow of the gas, and not allowing the time contact necessary for the absorption of the constituents it is desired to extract.

"*Livesey*" *Washer.*—The washer designed by Mr. George Livesey (see Drawing No. 4) consists of a rectangular cast-iron box, the upper part being formed into an inlet chamber,

together with one or two outlets. To the lower flanges of these inlet chambers are fastened a series of wrought-iron tubes—a piece of which is on the table—having holes one-sixteenth of an inch in diameter. The interior of these tubes is in communication at the ends with the outlet chambers, while the spaces between them at the ends are securely closed up. The gas has free access from the inlet chamber direct to these intermediate spaces, passing down them in the direction indicated by the arrows in the diagram, and depressing the liquor until the gas escapes through the inclined portion of the perforated plate to the first space, which is filled with liquor, through which it bubbles until it comes in contact with the horizontal part of the perforated plate, carrying some of the liquor with it to the upper surface of the plate. The bubbles of gas pass through this liquor into the tube space and convert the surface into light foam, which flows along with the gas into the outer chambers. The liquor drains from the washer by means of overflow pipes, by which the level can be adjusted as required. The inlet for the liquor supply is placed at the lower part of the washer. Glass windows are fixed in the sides at opposite ends of the tubes, so that the bubbling and washing of the gas in the tubes may be clearly observed. Special provision is made in the lowest part of the chamber for the collection of the tar, which is separated, and falls to the bottom, being drawn off from that level independently of the liquor at regular periods. The apparatus possesses the great advantage of being absolutely automatic, and requiring only a trifling amount of attention; while, for its compactness and the small space occupied, it is probably the most economical and efficient type in existence. By the minute subdivision of the gas, which is brought twice into contact with the liquor, the entire removal of all the tar, and the greater part of the ammonia, is ensured. In some works the ammoniacal liquor from the tower scrubbers flows by gravitation *viâ* a tar and liquor separator direct into the washer, which is fixed at a desirable level for the purpose. The number of perforations through which the gas has to pass per foot of trough is 3264, thus dividing the gas into many thousands of streams. Where more than one of these washers is used they are placed at different levels, to admit of the liquor gravitating from the last one to the first. The extensive adoption of this washer is sufficient guarantee of its efficiency.

"Charles Hunt" Washer.—The "Charles Hunt" patent washer, Drawing No. 4, is in reality a combined washer and scrubber. It is perfectly automatic. It consists of a series of chambers placed one over the other. The gas enters at the base and issues through vertical tubes, over which are placed inverted troughs sealing each compartment in liquor. Water is admitted at the top, and descends from tier to tier to the bottom; so that the gas on entering meets with warm liquor, and in its ascent is subjected to cooler liquor, until at the outlet in the last chamber it meets clean water. This gradual cooling of the gas is in accordance with the consensus of opinion as being the best preventive for naphthaline stoppages.

This washer possesses the advantage of being readily adjusted for variable makes of gas. A series of test cocks are provided for ascertaining the actual duty performed in each chamber. In the lower tiers, when desired, weak ammoniacal liquor from the hydraulic main and condensers can be admitted. One of the chief features is the enormous area of washing surface presented to the gas. The small ground area required by the apparatus is a great advantage, especially where the site is limited. The adjustment of the depth of seal in each chamber can be made while working in a few moments. It is a most efficient apparatus.

Marshall's Scrubber and Condenser.—Mr. Marshall, of the Copenhagen Works of the Danish Gas Company, has designed an effective combined condenser and scrubber. The gas passes in a downward direction between tubes, through which water is pumped in an upward one, the warm gas thus meeting at the inlet with a moderately warm condensing surface, and is gradually cooled in its passage through the apparatus. Water is dripped over the exterior of the water tubes, and the condenser becomes an effective scrubber, as the tubes present a considerable area of wetted surface; while a secondary effect of the trickling water is to clean the tubes from any deposit of tar, &c. The water is prevented from running down the sides of the condenser by a series of drain plates. One battery of seven sections is capable of condensing 350,000 cubic feet of gas per twenty-four hours from 142° to 63° F., the temperature of the inlet water being 60° F. The consumption of water to effect this result averages 5000 gallons. The battery contains 1054 square feet of water surface, and 204 square feet of air surface.

The apparatus is automatic, and does not require machinery other than for water purposes.

Anderson's Washer.—Mr. Anderson has always strongly advocated the use of washers. His design is composed of a chamber, containing a number of trays, underneath which a series of serrated bars extend from side to side. Weak liquor is admitted at the top. The trays seal in liquor, and the gas issues through them minutely divided.

Young's Washer.—The washer designed by the late Mr. Hugh Young, the engineer of the extinct Birmingham and Staffordshire Gas Company, consisted simply of high cast-iron rectangular vessels filled with wooden boards, through which the gas traverses up and down in two or more sections, being thoroughly drenched with liquor, a continuous supply of which descends from the top.

Reid's Washer.—Mr. John Reid's rotary washer for the Edinburgh and Leith Gas Commissioners, consisted of two hollow cylinders, all round which were fixed buckets, giving the appearance of a large water wheel. The wheels, revolving in a tank of liquor, discharge their contents inside the cylinders, which are revolved by a rack fixed on their circumference actuated by a pinion.

"*Holmes*" *Washer.*—Messrs. W. C. Holmes & Co.'s patent scrubber-washer (see Drawings Nos. 3 and 4) is in successful use in many gas-works. It is of the horizontal rotary form. The washing substance therein consists of a series of brushes made from a weed which has grown in water, thus ensuring a minimum amount of decomposition from the liquid contact. Such brushes contain an enormous quantity of wetted impinging surface for the small space occupied. This scrubber-washer, in addition to being one of the most efficient for removing ammonia, is also being used with considerable success in connection with cyanogen plants.

Kirkham's Washer-scrubber. — This "Standard" washer-scrubber is of the horizontal rotary type (see Drawing No. 4). The purifying action consists in the gas passing at all points over a wetted surface composed of constantly revolving wood grids. These grids are arranged in a series of horizontal compartments, the division plates forming them permitting the water to overflow from one compartment to another. The gas in passing through in this manner comes in contact last of all at the outlet

with clean water. The "internal bundles" were formerly made of perforated plates, but in order to reduce the weight for the driving, &c., wood has been substituted. It is one of the most popular forms of washer-scrubber in existence.

Whimster's Washer and Exhauster.—Mr. Thomas Whimster's combined exhauster and washer, made by Messrs. Hanna, Donald and Wilson, possesses several features of interest. A horizontal cylinder is divided into three compartments. Between these partitions there are a pair of revolving discs connected by a number of curved blades, thus constituting a series of bucket-like chambers. The gas entering the central division is carried down by the aforesaid curved blades below the liquor level, and escapes through openings at the centre of the revolving drum, and up through the liquor into two side divisions provided with outlets. The principle of thus exhausting the gas during the washing operation is worthy of further development and adaptation.

Laycock and Clapham's Washer.—This is of the rotary horizontal type, consisting of compartments in which cylinders fastened on the central shaft and filled with wood balls, revolve in ammoniacal liquor; thus ensuring the complete passage of the gas through, and in contact with, a large area of fresh and continuously wetted material.

Cathel's Washer.—The washer by Mr. E. S. Cathel is composed of a series of small washers, each of which is complete. They are elevated one above the other successively, and have also been placed one over the other vertically.

Walker's Purifying Machine.—Messrs. C. and W. Walker's machine consists, as illustrated in Drawing No. 1, of a rectangular vessel containing in its lower part a washing chamber, having on each vertical side numerous horizontal troughs open at the bottom, which have fine perforated slits on each side. The washing chamber is filled with liquor to the level of these perforations. The gas entering the receiver fills the troughs, from which it displaces a quantity of ammoniacal liquor, and passes through the immersed perforations. It then passes through the stronger liquor outside, and is thus relieved of its tarry particles, which fall through the liquor into the bottom chamber, and are subsequently drawn off. The gas, after leaving the washing chamber, ascends through rectangular openings over which are fixed the boxes of devices containing

wetted boards. These devices are fixed upon vertical shafts in connection with gearing for moving them up and down in the liquid. The gas passes from chamber to chamber between the wetted boards in each tier, until it arrives at the top free from ammonia and tar, together with a portion of the carbonic acid and sulphuretted hydrogen. The devices constantly dipping into the liquor, expose to the gas a large amount of wetted surface. The number of dips per minute adopted at Huddersfield is about six, and this in a three-million machine equals about ten millions of square feet per hour exposed to the gas; so that no portion of it can remain unwetted for more than one-sixth of a minute at a time. The action of this enormous wetted surface is to absorb the ammonia from the gas, thus forming strong ammoniacal liquor, which descends into the bottom washing chambers for the purpose of taking up the carbon dioxide. Clean water is admitted into the top at the rate of about ten gallons per ton of coal carbonised, and this water descends from chamber to chamber. Weak liquor is admitted into the bottom tiers. The liquor overflowing into the next lower tier of the machine meets the ascending streams of the gas nearly wholly free from ammonia. Only about 1 inch back pressure is thrown by this machine, which is a most efficient one. The power required for driving it is so small that a man can work the whole of the machine by taking hold of the fly-wheel and pulling it round with one hand.

Many different forms of washers and scrubbers have ingenious and interesting points with which the Members are familiar, such as—

The "Saville."

The "Coffey Still," which is sometimes used for a scrubber and washer.

Mr. Paddon's excellent washer-scrubber.

Mr. George Lowe's scrubber.

Mr. Warner's scrubber.

Mr. F. Southwell Cripps' washer.

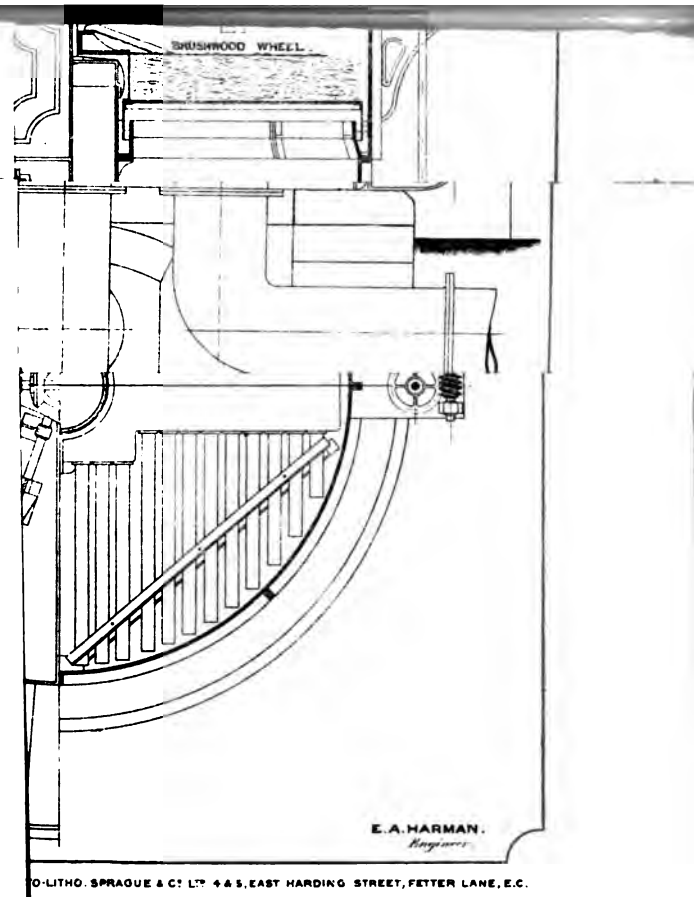
Mr. Cleland's steam scrubber,

Mr. Anderson's brush scrubber.

Messrs. Cockey and Sons; and many others.

The examples described will probably be sufficient illustrations, as representive of the various designs in use.

Ammonia.—Almost invariably upon gas-works, all the



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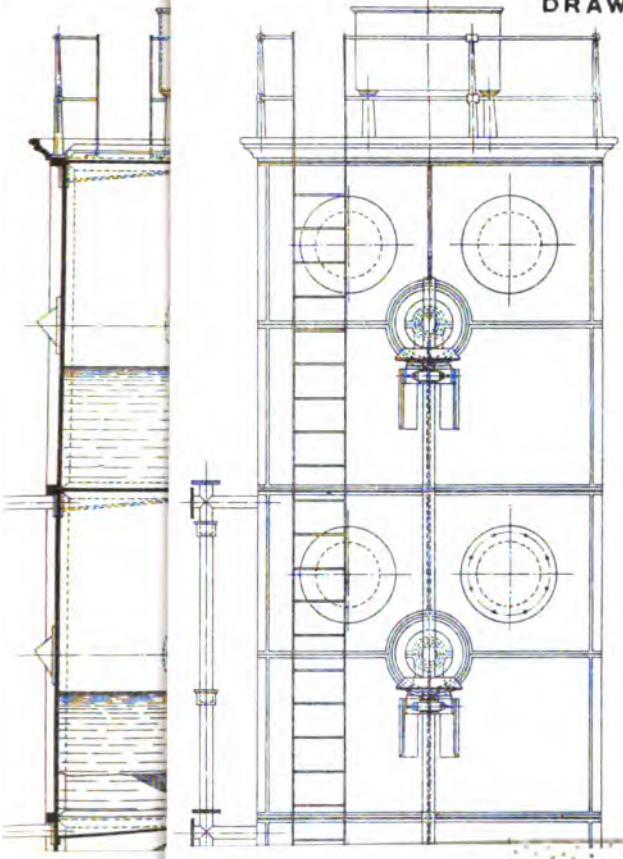
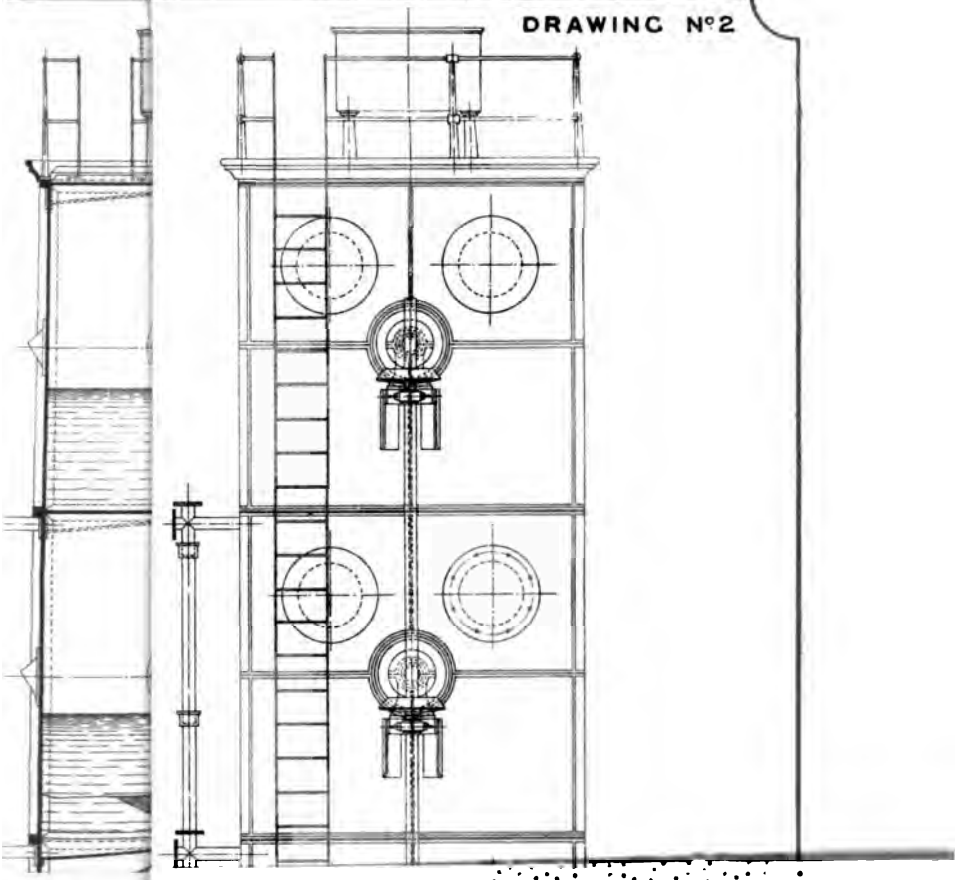
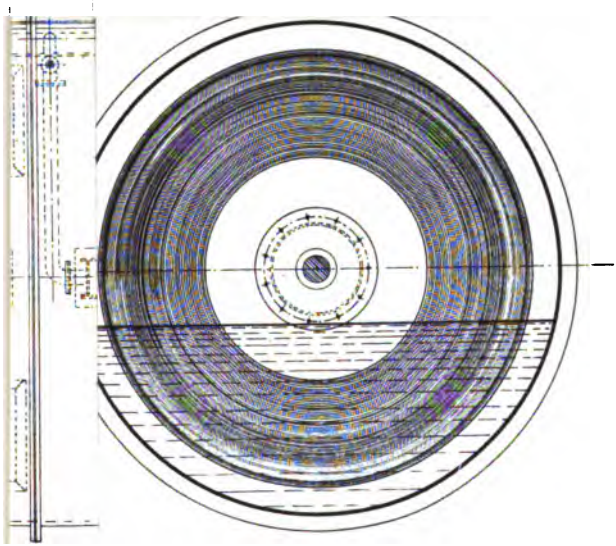
DRAWING Nº2



DRAWING Nº2





SECTION SHEWING BRUSH

E A HARMAN.
Engineer.

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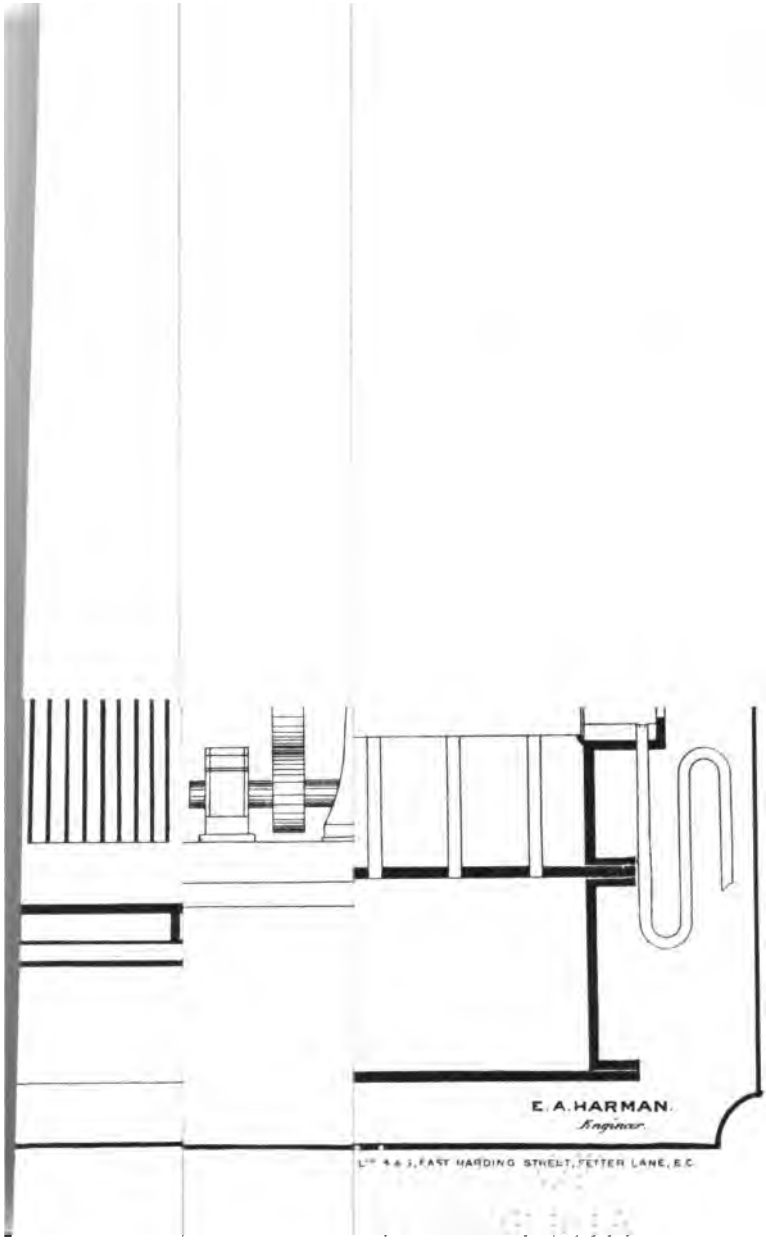

E. A. HARMAN.
Engineer.
Ltd 4 & 5, EAST HARDING STREET, FETTER LANE, E.C.

various ammoniacal liquors, whether from hydraulic mains, condensers, cooling mains, washers, scrubbers, &c., are drained into one common storage tank, although, having regard to the various compositions of these liquors, this is hardly a scientific way of dealing with them.

The question of the desirability of using purified liquor is too extensive for present consideration.

In Hill's process the ammoniacal liquor is passed through a kind of still, so regulated that about 50 per cent. of sulphuretted hydrogen and carbon dioxide present are liberated. The purified liquor, as it is termed, is then run back into washers, and is ready to take up another quantity of these impurities.

Ammoniacal liquor used in washers, unless purified by some such process, must not be allowed to be too heavily charged with carbon dioxide, or it will displace the sulphuretted hydrogen in a similar manner to that which obtains in the ordinary purifiers. The general principle is to heat ammoniacal liquor to a temperature of about 200° F., when the greater part of the carbon dioxide and sulphuretted hydrogen are driven off, the bulk of the ammonia being retained.

Comparatively little attention is paid to the properties of ammonia at various temperatures.

Coals contain 1 to 2 per cent. of nitrogen, and hold about 14 per cent. of this amount as ammonia during distillation at ordinary temperatures. This represents 5·7 lbs. of ammonia per ton of coal.

Thus

$$2240 \times 1{\cdot}5 \text{ per cent.} = 33{\cdot}6 \text{ lbs.} \times 14 = 4{\cdot}7 \text{ lbs. nitrogen.}$$

$$NH_3 = 17, \text{ molecular weight.} \quad N = 14.$$

$$\frac{4{\cdot}7 \times 17}{14} = 5{\cdot}7 \text{ lbs. of ammonia per ton.}$$

The weight of a cubic foot of ammonia is 316·77 grains.

Cannel coals generally contain less nitrogen than common coals. It is generally considered that Continental coals produce much less fixed ammonia than those in the United Kingdom. The nitrogen in coal may be reckoned distributed as follows:—

As ammonia	14·50	per cent.
As cyanogen	1·56	"
Free in gas, and combined in tar	35·26	"
Coke	48·68	"
	100·00	

Mr. Lewis Thompson recommended that a small percentage of ammonia should be left in the gas, to combine with the sulphur compounds and produce sulphate of ammonia, as being likely to have a sanitary influence. Owing to the reduction of sulphur compounds, and the increased purity of the gas now issued from gas-works, it is undesirable in every way.

Conclusion.—Failing a continuous process of purification in closed vessels, it is most desirable to get as large a percentage of purification done as possible in the existing closed vessels, such as have been enumerated. A good deal more could be done by liquid purification than is generally accomplished, and this principle was generally recognised in the early days of gas purification. It will be remembered that some forty or fifty years since a solution of sulphuric acid was used for purification, but the "acid boxes" have become extinct, on account of the affinity of sulphuric acid for the hydrocarbons. It is probable that a return in some improved form will be made sooner or later.

The Author realises that the foregoing remarks are but a trifling contribution to a most important subject.

DISCUSSION.

Mr. T. S. Lacey: We have a large number of Kirkham and Hulett's washers in operation at Beckton, but we found that the perforations in the washers became practically solid with deposit, stopping the passage of the gas, and rendering the washers completely useless. On examination I found that the difficulty was caused by a deposit of a double carbonate of magnesia and ammonia, the water of the well from which we drew our supply containing a large amount of magnesia. This magnesia gave us a great deal of trouble, not only with the washer, but with the other part of the apparatus, especially in the station meters. The cure for that part of our difficulty was the abandonment of the well water and the use of the East London Company's water.

The President: I am sorry that Mr. Harman's paper has had to be rushed through without being read or discussed, as it contains very interesting descriptions of every apparatus in use for washing.

Mr. HARMAN: It is only natural that different opinions should prevail in connection with the subject of this paper, and probably each of you have some pet theory as to purification. The suggestions I have advanced will, I am sure, be accepted in the spirit in which they are offered, that of enquiry. The importance of efficient treatment of the gas in these preliminary stages of purification is very great as affecting materially the subsequent operations. The question of the extended use of wet re-agents for the purification stages is so extensive that a whole paper might reasonably and properly be prepared upon the subject. As regards the sizes of the apparatus employed, I feel sure that due regard is not paid to the calculations necessary to insure plant of a correct capacity being erected. Some such method of calculation as is indicated in the paper will be of service in determining not merely the cubical area of an apparatus, but its actual working efficiency, which must alone be the determining factor in any case. The chemical changes taking place in washers and scrubbers are most numerous, varying with all the different liquors and temperatures in the processes. In fact so largely is the subject a chemical one as to be worth the attention of definite research work by expert chemists.

APPENDIX.

INCLINED RETORTS AT BRENTFORD.

COMMUNICATED BY J. HUSBAND.

These retorts are inclined at an angle of 31° and are 20 feet long, the section being 24½ inches by 14 inches ⌒. There are six retorts in each bed or arch, which is semicircular and 7 feet 10 inches span. Each bed of six retorts has its own regenerator furnace.

The coal is lifted from the barges in the river by a crane to which has been adapted the arrangement of elevating and conveying plant as shown on the diagram.

The retorts are "drawn" and "charged" every six hours, the weight of a charge averaging about 6¼ to 6½ cwt.

1 gang (8-hour shifts) consists of:—

		£	s.	d.
1 charger at 6*s.* 5*d.*	=	0	6	5
4 drawers at 5*s.* 6*d.*	=	1	2	0
1 pipe jumper at 5*s.* 9*d.*	=	0	5	9
1 fireman at 6*s.*	=	0	6	0
1 boy at 3*s.*	=	0	3	0
Total		2	3	2

Each gang works 16 sets = 256 mouthpieces

$$\left(\frac{16 \text{ sets} \times 12 \text{ mouthpieces} \times 4 \text{ charges per diem}}{3 \text{ shifts}}\right).$$

The weight of coal carbonised per shift is about 40 tons (256 mouthpieces = 128 retorts × 6¼ cwts. This works out at 1*s.* 1*d.* per ton.

These sets were first erected in 1890–1.

NOTE.—Owing to the rise in wages of stokers in the London district to the extent of 5*d.* per day, which is about to take place, the above prices must be increased accordingly.

INCLINED RETORTS AT SOUTHALL.

The retorts in this house are inclined at an angle of 36°, and are 15 feet long, the section being 21 inches by 13 inches ⌒.

There is no reason why these retorts should not work equally well 20 feet long; but the house in which these inclined sets were erected in the place of horizontals was not of sufficient width to take two benches of 20-feet retorts.

There are seven retorts in each arch, heated by regenerator furnaces of similar design to those at Brentford.

The charge per retort averages about 4½ cwt., the retorts being drawn and charged every six hours.

It will be seen from the diagram that the coal is run from the continuous storage hoppers overhead into travelling chargers (of which there are three to each bench—one for every tier of retorts), the sight-hole at the back affording a means of ascertaining when the full quantity of coal is in the charger. The bottom plate of the charger is set at the same angle as, and in a line with, the retort to be charged; there being provided a sliding shoot underneath and a vertical slide in front for allowing the coal to pass from the charger into the retort.

1 gang (8-hour shifts) consists of—

		s.	d.
2 men at 5*s.* 4*d.*	=	10	8
1 man at 5*s.*	=	5	0
⅔ man at 6*s.*	=	4	0
Total		19	8

Each gang works 8 sets = 112 mouthpieces.

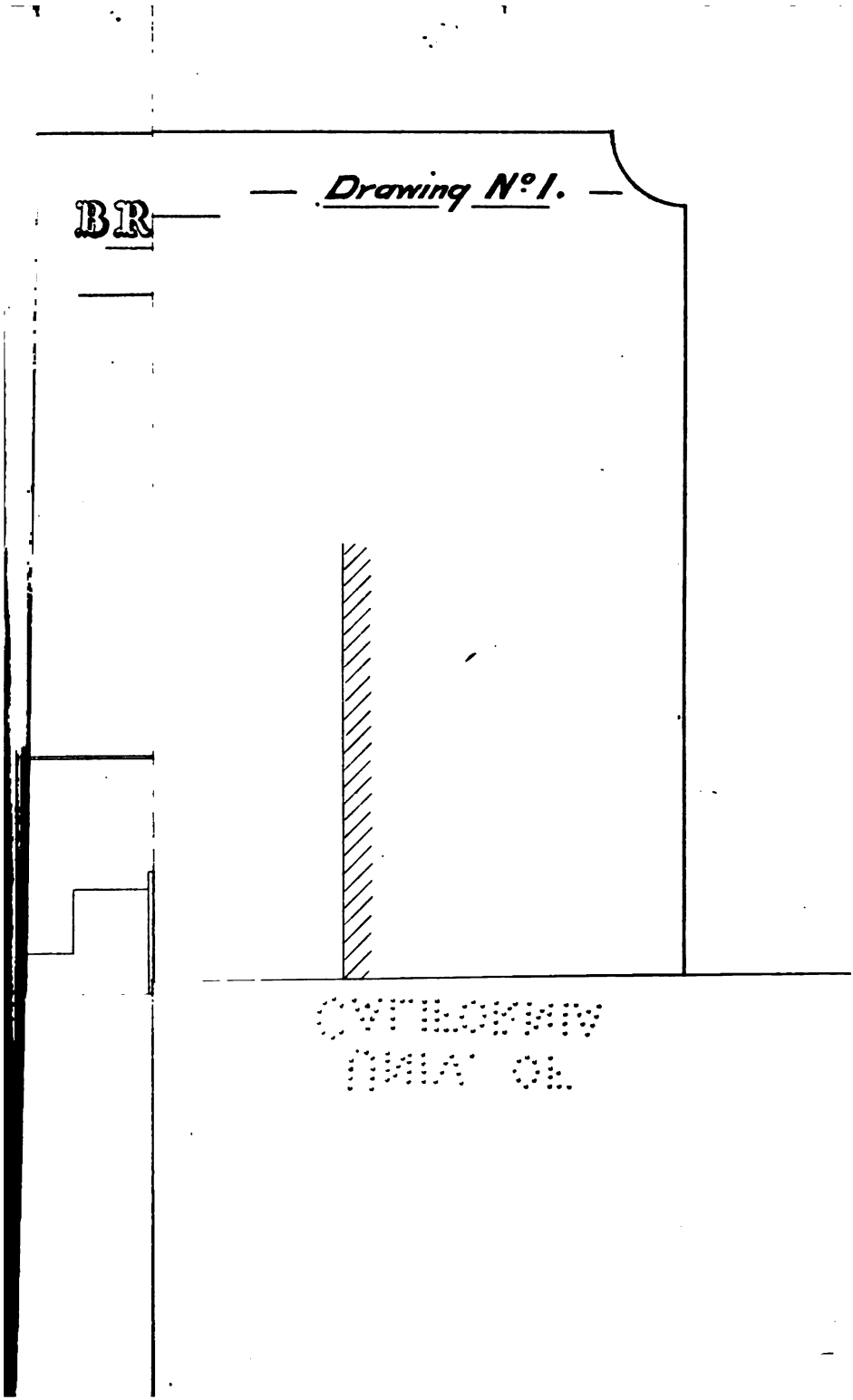
The weight of coal carbonised per shift is about 17 tons. This works out at 1*s.* 1·9*d.* per ton.*

With regard to the coke conveyors, these originally (in 1890) were fixed immediately in front of the sets, so that the hot coke fell on to them and was there quenched; but the wear and tear on the conveyors was too much, and consequently they were moved to the position shown on the diagram, the coke being quenched under the stage in the usual manner, and then thrown back on to the conveyors.

The first "through" inclined retort was erected by this company and experimented with in September 1889. It was 15 feet long.

The first 20-feet "through" inclined sets were erected and worked at Southall in 1890. The 15-feet sets were erected in 1891.

* See Note on preceding page.


Drawing No. 1.
BR

— Drawing No. 2. —

NTP

GASHOLDER AND TANK FOR THE NEWCASTLE-UPON-TYNE AND GATESHEAD GAS COMPANY.

COMMUNICATED BY W. DOIG GIBB.

The following descriptions have been abstracted from the Contract Specifications :—

"*Tank.*—The tank is to be 239 feet diameter inside, and 45 ft. 6 in. deep from the top of stone curb to the bottom level of concrete between the rest stones. The bottom of tank will be flat and horizontal for a distance of 8 ft. 6 in. from the wall all round, and the cone will rise from this point to the centre. For a distance of 48 feet measured horizontally, the slope will be 1 in 1½. It then changes, and is 1 in 48 to a point 6 feet from the centre, which 6 feet is level. The highest point of the finished cement mortar face of the cone will be 12 feet below the level of top of curb. The curbstone, which will run right round the top of wall between the piers, will be 18 inches broad and 15 inches deep, in lengths of not less than 3 feet, properly tooled to shape, wrought to the circle, and well bedded in cement mortar. The inside face next tank will be finished with a sharp square edge, and the outside will have the top corner bevelled off at an angle of 45 degrees, 3 inches each way, measured on the square. The stones forming curb must all be keyed together as shown on Drawing No. 94, with dove-tail keys 3 inches wide tapering to 2½ inches, and 3 inches long, cut right through the stones, and run with liquid cement and sand grout made in proportion of one part of cement to two parts of sand. The wall of tank will be formed of concrete, and will be 7 feet thick at the bottom for a height of 7 feet. From this point it will reduce with a regular batter, and will be 3 ft. 6 in. thick at the top under curb. The horizontal part of the tank bottom will be 3 feet thick, and the slope of cone will be covered with concrete 9 inches thick. The centre of cone will be thickened out in the form of a circular block 12 feet diameter and 3 feet thick. There will be 26 radial ribs under the floor of cone, starting at the bottom of tank and running into the centre pillar. These ribs will be 12 inches by 12 inches in section, and will be exactly in line between the standards and centre of tank. There will also be four steps on the slope of cone, each running right round the tank as shown. These steps are worked out of the solid side of cone, and will each be 2 ft. 6 in. wide on the flat, and have their upper face truly hori-

zontal, to receive the column feet. There will be 26 piers in the wall of tank, equally divided out in the circumference, and they will each be 9 ft. 5 in. by 6 ft. 1 in. measured from the inside face of tank wall, and will run the full section from top to bottom. The top will be finished with four stones bedded in cement mortar, and having the whole of the upper face dressed absolutely true and level, and left perfectly smooth. The sides and ends will also be properly tooled and dressed smooth and vertical, and have the top edge on three sides bevelled as specified for the coping. The four stones forming the top of pier will in every case be keyed together as shown on Drawing No. 94, and specified for coping. There will be six holding-down bolts 2½ inches diameter, and of the length shown on drawings, built into each pier and furnished with anchor plates at the lower end. There will be six cast-iron overflow pipes in the circumference of the tank. These pipes will be of the form and dimensions shown on Drawing No. 91, and must be built into the curb stones in the positions shown on plan. There will be 15 circular wall ties formed of rings of bar iron 6 inches by ⅜ inch, in lengths of not less than 15 feet and not more than 30 feet, riveted together with lap joints, and built into the wall in positions shown on section. There will be 52 steel tank guides fixed round the tank, at equal distances apart, 26 of 8 inch by 3¼ inch channel steel, and 26 of 6 inch by 3 inch channel steel. Each 8 inch by 3¼ inch channel guide will be secured to the concrete of wall by means of eight lewis bolts, let 7 inches into wall, and by two lewis bolts at top, let 5 inches into stone coping and run with lead. Each 6 inch by 3 inch channel guide will be secured to concrete of wall by eight lewis bolts, let 7 inches into wall and run with lead, and the top will be secured to a small casting by means of two countersunk bolts, as shown. The face of concrete, where each guide rail is fixed, must be perfectly vertical and true from top to bottom, in order that the guide rails, when fixed, may all stand truly perpendicular, and present a level even face to the rollers. There will be 26 cast-iron brackets on the top of coping for securing ends of intermediate 6 inch by 3 inch guides. Each of these brackets will be held down with four lewis bolts, as shown, let 5 inches into stone, and run with lead. There will be 52 rest stones in the bottom of tank, each 6 ft. 6 in. by 2 feet by 1 foot. They will project 6 inches above the bottom of tank when bedded, and all their top faces must be dressed smooth, and must be at one dead level round the tank and truly horizontal. They must also be all fixed exactly opposite and in radial line with the centres of the guide rails. The wall of the tank will be thickened out to form a pier round the inlet and outlet pipes, which will be built in solid. The pier will be of the sizes shown on drawings; and

the concrete will be thickened round the horizontal part of the pipes and the bends. The inlet and outlet pipes will be supplied, together with all bolts, rivets, jointing material, &c., and delivered on site by the contractor for gasholder, who will also send a competent inspector to supervise the erection. The contractor for tank will be required to erect in position and make all the joints in the pipes to the satisfaction of the inspector for the gasholder contractor. The joints must all be made with a mixture of red and white lead and boiled oil, and the pipes will be tested under a water pressure of 100 feet. The jointing up of pipes must be performed by experienced practical men only. There will be a hollow shaft or pier of brickwork on the centre of the cone. The internal diameter will be 3 ft. 5 in. from top to bottom. The external diameter at the bottom will be 6 ft. 8 in., with two footsteps in addition on to the concrete; and at a height of 21 feet there will be a square step in, and the diameter will be reduced to 5 ft. 10 in. for a further distance of 9 ft. 11½ in., when another square step will reduce the diameter to 4 ft. 11 in. The total height will be 31 ft. 9 in.

"The whole of the excavations to be made to the full depth shown, and the trenches for walls properly shored and timbered so as to leave the various sections of wall full and square. The clay on the surface of cone must be carefully dressed to shape, and channels for ribs cut clean and square, and all loose matter cleared out before concrete is put in. The whole of the mortar used must be composed of one part of Portland cement (from a first-class maker) to three parts of clean, sharp sand, measured dry and net. The cement must be of such a degree of fineness that not more than 10 per cent. by weight of it will remain as a residue on a wire screen of 5800 meshes to the square inch, and must weigh not less than 112 lbs. per imperial bushel. It will be tested, from time to time during the progress of work, for cohesive strength and setting properties, and there must be a cohesive strength in the pure cement of 350 lbs. per square inch after seven days' immersion in water. The sand must be clean, sharp river sand, free from dirt or salt and finely screened. The cement must be emptied from the bags on to a covered floor (which the contractor must provide) and be exposed for at least 24 hours before being used. The whole of the concrete must be composed of one part of Portland cement as above, and six parts of gravel, measured dry and net. The gravel must be composed of three parts of coarse screened stones broken to such a size as will pass through a 1½ inch ring, and three parts of clean sharp river or pit sand. The materials must first be mixed dry on a platform, and turned over twice, then watered with just sufficient water to moisten them, turned over three times, and thrown into position from a height of not more than 5 feet,

and well beaten down and packed with the shovel to the sides of excavation, well rammed and grouted into a compact mass with liquid cement and sand grout at every course. The concrete must be deposited in layers of 1 foot, and the total depth laid in one day must not exceed 3 feet. Each layer of 1 foot must be properly grouted and levelled. The faces of all excavations must be smoothly dressed off and completely freed from all loose material, and the concrete placed so that while it measures its full dimensions it shall also completely and entirely abut on the solid dressed off faces of the excavations.

"The whole of the inside face of tank wall, the bottom of tank, and the whole surface of cone, must be finished and trowelled off smoothly with cement mortar ¾ inch thick, consisting of one part of Portland cement to two parts of sand, all as before described. All bricks used must be sound, hard burnt, picked bricks of an approved quality, even colour and regular shape. Specially moulded bricks must be procured wherever necessary for curves, bevels, beads, &c. No bricks containing lime will be allowed to be used for any part of the contract. The brickwork must be laid in English bond, i.e. rows of headers and stretchers alternately, and none but whole bricks must be used. All bricks must be well wetted before being laid. Joints must not be more than ¼ inch thick, and every second joint must be well grouted with liquid cement grout, the interior of the walls being run up solid, and not merely lipped with cement round the outside. The external face of all brickwork must be neatly pointed with ruled joints, and all courses must be truly horizontal. The stone used throughout the whole of the contract must be of the best quality ashlar worked and fair tooled on the beds, joints, and faces, and free from all flaws and discoloration. The name of the quarry from which stone is to be obtained, as well as a sample of the stone, must be submitted for the approval of the engineer before any is ordered. The stone must all be properly dressed and tooled as required, and the arrises and angles left square and true. Patched or defective stones will not be allowed to be used, and any stones which may be found damaged or defective before the contractor's liability ceases must be replaced. All joints must be close and clean made with the smallest amount of cement possible. The contractor must undertake to deliver over the tank to the company at the time stipulated in this specification, sound, watertight, in good condition, and in all respects to the approval of the engineer. The tank will then be filled with water by the company and carefully examined for any leakage or weakness. Should any defects of any kind be discovered, then or at any time during the twelve months' maintenance by the contractor, he will be required to remedy same, and as often as may be necessary

for this purpose to empty the whole of the water out and fill the tank again entirely at his own expense.

"*Gasholder.*—The gasholder will consist of three lifts, steel guide framing, and inlet and outlet pipes. The outer lift will be 236 feet diameter and 45 feet deep. The top and bottom rows of sheeting will be $\frac{3}{8}$ inch thick and 3 feet wide, and the second row of plates, top and bottom, will be $\frac{1}{4}$ inch thick and 3 feet wide. The whole of the intermediate sheeting will be No. 10 B.W.G. in thickness. There will be 52 vertical strips 1 ft. 6 in. wide and $\frac{3}{8}$ inch thick, riveted to the $\frac{3}{8}$ inch plates at the top and bottom, and running the full height of the lift between. There will be 52 channel steel guide bars the full depth of the lift 6 inches by 3 inches by $\frac{1}{2}$ inch by 19 lbs. per foot, secured to the sheeting inside by means of 3 inch by 3 inch by $\frac{1}{2}$ inch angle steel bars as shown, and 104 channel steel bars on the outside $3\frac{1}{4}$ inches by 3 inches by $\frac{1}{2}$ inch by 15 lbs. per foot, riveted to the 18 inch by $\frac{3}{8}$ inch strips, 6 inches apart. The bottom curb will be composed of two 9 inch by $\frac{5}{8}$ inch plates, and three $4\frac{1}{2}$ inch by $4\frac{1}{2}$ inch by $\frac{5}{8}$ inch angles as shown on drawing, riveted with $\frac{7}{8}$ inch rivets, 6 inch pitch. The hydraulic grip will be composed of 12 inch by $3\frac{1}{2}$ inch by $\frac{5}{8}$ inch steel channel, weighing 37 lbs. per foot run, and $\frac{3}{8}$ inch steel plate 2 feet wide, riveted together with $\frac{3}{4}$ inch rivets, $2\frac{1}{2}$ inch pitch. The lower edge of steel plate will be stiffened by means of a bead of 3 inch by $\frac{1}{2}$ inch half round iron riveted to it with $\frac{3}{4}$ inch countersunk rivets, 6 inch pitch. The joints in the channel will be covered with $\frac{3}{4}$ inch plates 2 ft. 4 in. long, riveted as shown on drawing. There will be 104 rest pieces in the grip, riveted to the channel with $\frac{3}{4}$ inch rivets, and spaced equidistant round the circumference.

"There will be 26 top carriages formed of steel plates and angles riveted together as shown on Drawing No. 100, and fitted with turned cast-iron rollers 12 inches diameter by $3\frac{1}{2}$ inches wide on face, working on turned pins of forged steel 2 inches diameter, reduced to $1\frac{3}{4}$ inch diameter at the ends. The rollers will be bored out, and fitted with $\frac{3}{8}$ inch steel bushes. The carriages will be provided with slot holes, and have adjusting plates $4\frac{1}{2}$ inches by $\frac{5}{8}$ inch thick, each secured with $\frac{3}{4}$ inch studs. These adjusting plates must be cut to length, and fitted in when rollers are in final position. A small angle stay, composed of $\frac{3}{8}$ inch plate and 3 inch by $2\frac{1}{2}$ inch by $\frac{1}{2}$ inch angles, will be riveted to the 12 inch by $3\frac{1}{2}$ inch channel at the back of each $3\frac{1}{4}$ inch by 3 inch by $\frac{1}{2}$ inch vertical channel. There will be 52 bottom carriages fitted in between the 9 inch by $\frac{5}{8}$ inch plates of bottom curb. These carriages will be composed of $\frac{5}{8}$ inch plates and 3 inch by 3 inch by $\frac{5}{8}$ inch angles riveted together and to the curb as shown on Drawing No. 100, and fitted with turned cast-iron rollers 12 inches

diameter by $3\frac{1}{2}$ inches wide on face, working on turned pins of forged steel $1\frac{3}{4}$ inch diameter, reduced to $1\frac{1}{2}$ inch diameter at the ends. The rollers will be bored out, and fitted with $\frac{3}{8}$ inch steel bushes. The carriages will also be provided with slot holes, and have adjusting plates $4\frac{1}{2}$ inches by $\frac{5}{8}$ inch thick, each secured with $\frac{3}{4}$ inch studs. These adjusting plates must be cut to length and fitted in when rollers are in final position. There will also be 52 intermediate stays fixed between the $\frac{5}{8}$ inch plates of bottom curb, midway between the bottom carriages, and formed of $\frac{1}{2}$ inch plate and 3 inch by 3 inch by $\frac{1}{2}$ inch angles. There will be an oval manhole in the upper tier of $\frac{1}{4}$ inch plates, 2 feet by 1 ft. 6 in. clear opening, with $\frac{3}{8}$ inch cover secured by $\frac{5}{8}$ inch studs, and having 3 inch by $\frac{1}{2}$ inch welded ring riveted inside. The riveting and lap of the various seams will be as shown on Drawing No. 101, and all rivets above $\frac{3}{8}$ inch diameter must be put in hot. The middle lift will be 233 feet diameter and 44 feet deep. The top and bottom rows of sheeting will be $\frac{3}{8}$ inch thick and 3 feet wide; the next row top and bottom will be $\frac{1}{4}$ inch thick and 3 feet wide. The whole of the intermediate sheeting will be No. 10 B.W.G. in thickness. There will be 52 vertical strips 1 ft. 6 in. wide and $\frac{3}{8}$ inch thick, riveted to the $\frac{3}{8}$ inch plates top and bottom, and running the full height of the lift between. There will be 52 channel steel guide bars the full depth of the lift, 6 inches by 3 inches by $\frac{1}{2}$ inch by 19 lbs. per foot, secured to the sheeting inside by means of 3 inch by 3 inch by $\frac{1}{2}$ inch angle steel bars, as shown on Drawing No. 100, and 104 channel steel bars on the outside $3\frac{1}{4}$ inches by 3 inches by $\frac{1}{2}$ inch by 15 lbs. per foot, riveted to the 18 inch by $\frac{3}{8}$ inch strips, 6 inches apart. The hydraulic cup and grip will be composed of 12 inch by $3\frac{1}{2}$ inch by $\frac{5}{8}$ inch channel steel and $\frac{3}{8}$ inch plate, as specified for the outer lift grip. There will also be 104 rest pieces in cup, and 104 in grip. There will be 26 top carriages formed of steel plates and angles, riveted together as shown on Drawing No. 100. The carriages will be fitted with main rollers of cast iron 1 ft. 6 in. diameter and 4 inches wide on the face, working on turned pins of forged steel 2 inches diameter, reduced to $1\frac{3}{4}$ inch diameter at the ends. The rollers will be bored and fitted with $\frac{3}{8}$ inch steel bushes. The carriages will also be provided with slot holes, and be fitted with an adjusting arrangement as shown, and the rollers will finally be secured in position by means of forged packings, cut and fitted after adjustment. Each carriage will also be provided with two side rollers, working at right angles to the main roller. These side rollers will be of cast iron, turned and bored, and fitted with $\frac{3}{8}$ inch steel bushes. Each roller will work on the end of a forged rectangular bar 3 inches by $2\frac{1}{2}$ inches, reduced to $1\frac{3}{4}$ inch diameter in the roller, and secured to the plate by means of $1\frac{1}{8}$ inch adjustable

bolts. The bars will finally be secured in position by means of packings cut and fitted after adjustment. The carriages will be securely held in position by means of wing stays of 5 inch by 3 inch by $\frac{5}{8}$ inch angle steel. There will be 52 bottom carriages, formed of $\frac{1}{2}$ inch steel plates and 3 inch by 3 inch by $\frac{1}{2}$ inch angles riveted together, and to the underside of hydraulic cup. The carriages will be fitted with turned cast-iron rollers 10 inches diameter by $3\frac{1}{2}$ inches wide on the face, working on turned pins of forged steel $1\frac{1}{2}$ inch diameter, reduced to $1\frac{1}{4}$ inch diameter at the ends. The rollers will be bored out and fitted with $\frac{3}{8}$ inch steel bushes.

"The carriages will also be provided with slot holes, and have adjusting plates $3\frac{1}{2}$ inches by $\frac{5}{8}$ inch, each secured with $\frac{3}{4}$ inch studs. These adjusting plates must be cut to length and fitted in when rollers are in final position. There will be an oval manhole in the upper tier of $\frac{1}{4}$ inch plates, 2 foot by 1 ft. 6 in. clear opening, with $\frac{3}{8}$ inch cover, secured by $\frac{5}{8}$ inch studs, and having 3 inch by $\frac{1}{2}$ inch welded ring riveted inside. The riveting and lap of the various seams will be as shown on Drawing No. 101, and all rivets above $\frac{3}{8}$ inch diameter must be put in hot. The inner lift will be 230 feet diameter and 44 feet deep. The top row of plates next the curb will be $\frac{5}{8}$ inch thick and 3 feet wide, and the next row $\frac{1}{4}$ inch thick and 3 feet wide. The bottom row of plates next the cup will be $\frac{3}{8}$ inch thick by 3 feet wide, and the next row $\frac{1}{4}$ inch thick by 3 feet wide. The whole of the intermediate sheets will be No. 10 B.W.G. in thickness. There will be 52 vertical strips 1 ft. 6 in. wide and $\frac{3}{8}$ inch thick, riveted to the $\frac{5}{8}$ inch plate at top and to the $\frac{3}{8}$ inch plate at bottom, and running the full height of lift between. There will be 52 vertical stays of girder section formed of 3 inch by 3 inch by $\frac{1}{2}$ inch angles and $\frac{3}{8}$ inch web plates, and braced together with $2\frac{1}{2}$ inch by $\frac{3}{8}$ inch lattices. The angle frames will be welded solid, and the top of stays shaped out to fit the rise of crown; all as shown on Drawing No. 100. The hydraulic cup will be similar in all respects to that of the middle lift. The top curb will be formed of angle steel 6 inches by 6 inches by $\frac{7}{8}$ inch, properly splayed out to fit the rise of the crown, and set to the radius of holder. It must be in lengths of not less than 14 feet, and jointed with covers 3 feet long by $5\frac{1}{8}$ inches by $5\frac{1}{8}$ inches by 1 inch. The rivets through both legs of the angle will be $\frac{7}{8}$ inch diameter and 4 inch pitch zigzag. There will be a circular stay composed of 12 inch by $\frac{3}{8}$ inch plate, and two 6 inch by 4 inch by $\frac{1}{2}$ inch angles running right round the underside of crown at the top-end of vertical stays, and riveted to crown plates and vertical stays. The angles will be riveted to plate by means of $\frac{3}{4}$ inch rivets, 6 inch pitch, as shown, and will be jointed with $5\frac{1}{2}$ inch by $3\frac{1}{2}$ inch by $\frac{5}{8}$ inch covers 3 feet long. The plate will also have covers 2 feet by

12 inches by $\frac{3}{8}$ inch, as shown. Round the bottom of lift, and running from one vertical stay to another, will be horizontal stays of tee steel 6 inches by 4 inches by $\frac{1}{2}$ inch. These stays will have the ends properly smithed to the angle, and will not be set to the curve. The $\frac{5}{8}$ inch plates in top row will be butt-jointed, with cover strips 8 inches by $\frac{3}{4}$ inch riveted with $\frac{7}{8}$ inch rivets. The outer row of crown plates will be $\frac{3}{4}$ inch thick and 4 feet wide, and butt-jointed with 9 inch by $\frac{7}{8}$ inch covers. The next row of plates will be $\frac{1}{2}$ inch thick by 4 feet wide, and butt-jointed with 7 inch by $\frac{5}{8}$ inch covers. The third row of plates will be $\frac{1}{4}$ inch thick and 3 feet wide, lap-jointed. The centre plate will be 6 feet diameter by $\frac{3}{8}$ inch thick; and the next row $\frac{1}{4}$ inch thick by 5 feet wide. The whole of the intermediate sheets will be No. 9 B.W.G. in thickness, and will be radial. There will be 26 top carriages formed of steel plates and angles riveted together, as shown on Drawing No. 100. The carriages will be fitted with main rollers of cast iron 2 feet diameter, bored out and bushed with $\frac{3}{8}$ inch steel bushes, and working on turned pins of forged steel $2\frac{1}{2}$ inches diameter, reduced to $2\frac{1}{4}$ inches diameter at the ends. The carriages will have slot holes in the cheeks, and will be fitted with an adjusting arrangement as shown, and the rollers will finally be secured in position by means of forged packings cut and fitted after adjustment. Each carriage will also be provided with two side rollers working at right angles to the main roller. These side rollers will be of cast iron, turned and bored, and fitted with $\frac{3}{8}$ inch steel bushes. Each roller will work on the end of a rectangular forged steel bar 3 inches by $2\frac{1}{2}$ inches, reduced to $1\frac{3}{4}$ inch diameter in the roller, and secured to the plate by means of $1\frac{1}{8}$ inch adjustable bolts. The bars will be finally secured in position by means of packings, cut and fitted after adjustment. The carriages will be securely held in position by means of wing stays of 5 inch by 3 inch by $\frac{5}{8}$ inch angle steel, and will each be fixed to the crown by means of 22 studs, 1 inch diameter, screwed through $\frac{3}{4}$ inch plate, and having nuts above and below. There will be 52 bottom carriages, formed of $\frac{1}{2}$ inch steel plates and 3 inch by 3 inch by $\frac{1}{2}$ inch angles riveted together and to the underside of hydraulic cup and to back of vertical stay.

"These carriages will be fitted with turned cast-iron rollers, 10 inches diameter by $3\frac{1}{2}$ inches wide on face, bored out and bushed with $\frac{3}{8}$ inch steel bushes, and working on turned pins of forged steel $1\frac{1}{2}$ inch diameter, reduced to $1\frac{1}{4}$ inch diameter at the ends. The carriages will have slot holes at the cheeks, and will be fitted with $3\frac{1}{2}$ inch by $\frac{5}{8}$ inch adjusting plates, cut and fitted after final adjustment, and secured by $\frac{3}{4}$ inch studs. There will be two circular manholes in crown, 3 ft. 6 in. diameter, with $\frac{3}{8}$ inch covers, and $3\frac{1}{2}$ inch by $\frac{1}{2}$ inch rings inside. The covers will be secured by $\frac{3}{4}$ inch set

studs, tapped through crown plate and ring, and the manholes will be arranged to come directly over the inlet and outlet pipes. There will also be a circular manhole, 2 ft. 6 in. diameter, in the centre of the centre crown plate, fitted with $\frac{3}{8}$ inch cover and 3 inch by $\frac{1}{2}$ inch welded ring, and having a short 3 inch diameter double-flanged piece riveted on the centre, to take the blow-off cock. The crown will rise 20 feet in the centre, from the horizontal line, and be set out to a true curve with a radius of 340 ft. $7\frac{1}{2}$ in. The riveting and lap of the various seams will be as shown on Drawing No. 101, and all rivets above $\frac{3}{8}$ inch diameter must be put in hot. There will be 26 tank guides in line with the standards, reaching from the top of the rest stones to the top edge of coping. The guides will be of channel steel 8 inches by $3\frac{1}{4}$ inches by $\frac{1}{2}$ inch by $23\frac{1}{2}$ lbs. per foot run. Each guide will have five plates riveted to the back of it, 1 ft. 4 in. by 8 inches by $\frac{1}{2}$ inch, the rivets being countersunk on both sides. Each plate will be secured to wall by means of two lewis bolts $\frac{7}{8}$ inch diameter, let 5 inches into stone and 7 inches into concrete. There will be 26 tank guides fixed midway between the standard guides, and reaching from the top of rest stones to 12 inches above the level of coping. These guides will be of channel steel, 6 inches by 3 inches by $\frac{1}{2}$ inch by 19 lbs. per foot run. Each guide will have four plates riveted to the back of it 1 ft. 2 in. by 8 inches by $\frac{1}{2}$ inch, the rivets being countersunk on both sides. Each plate will be secured to the wall by means of two lewis bolts $\frac{7}{8}$ inch diameter, let 7 inches into concrete, and run with lead. The top ends of guides will be held in position by 26 cast-iron brackets, each secured to stone coping by means of four bolts $\frac{7}{8}$ inch diameter, let 5 inches into stone, and run with lead. The inlet and outlet pipes will be 3 ft. 6 in. diameter inside, and will be formed of $\frac{1}{2}$ inch steel plate, butt-jointed, with 5 inches by $\frac{1}{2}$ inch cover strips, riveted with $\frac{3}{4}$ inch rivets, $2\frac{1}{2}$ inch pitch. The flanges will be formed of angle steel welded rings 4 inches by $3\frac{1}{2}$ inches by $\frac{3}{4}$ inch. These rings must be turned up true in a lathe after being riveted to the pipes, and must be not less than $\frac{1}{2}$ inch thick when finished. There will be one longitudinal joint only in all the pipes. There will be two tee pipes, all of steel plate and angles as shown, with proper cover strips to both vertical, circular, and mitre joints, and $\frac{7}{8}$ inch cover plates on the top, secured by means of $\frac{3}{4}$ inch bolts, and having 12 inches diameter holes cut through for syphon pipes. There will be two syphon boxes formed of steel plates and angles, 5 feet by 5 feet by 5 ft. 10 in. high inside. The top and bottom angles will be solid welded frames, and the vertical corner angles joggled over them. There will also be three vertical stiffeners of tee steel 5 inches by 3 inches by $\frac{1}{2}$ inch, joggled over the angles and riveted to side

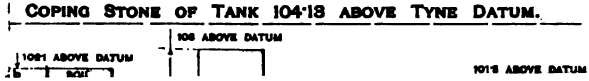
plates. The rivets in the boxes will be $\frac{3}{4}$ inch diameter and $2\frac{1}{2}$ inch pitch. There will be two duckfoot bends 7 feet radius on the centre, with turned angle flanges and base plates 8 feet by 2 feet by $\frac{1}{2}$ inch. The $\frac{1}{2}$ inch vertical web will be in two pieces, the joint being covered with 5 inch by 4 inch by $\frac{1}{2}$ inch tee bars. The two flanges must, when finished, be exactly at right angles to one another, and when standing level on the base plate must lead truly horizontal and vertical. The upper ends of the pipes inside will be finished with a 3 inch by $\frac{1}{2}$ inch ring, and must, when fixed, stand 2 inches above the top level of the tank coping. The pipes will stand 6 feet apart, centre and centre, and be secured together by a small stay of $\frac{1}{2}$ inch plate, and 3 inch by 3 inch by $\frac{1}{2}$ inch angles fixed 3 feet from the top. The inlet and outlet pipes will each be fitted with a syphon pump and pipes, as shown on Drawing No. 92A. The syphon pipes will be of wrought iron $1\frac{1}{4}$ inch diameter, and will start 9 inches from the bottom and run up a distance of 25 feet, and will then be screwed into a brass pump barrel, bored out to $2\frac{1}{2}$ inches diameter, in which the plunger will work. The top of pump barrel will be flanged, and a 3 inch diameter wrought-iron pipe bolted on, running to the top. The whole of this arrangement will be enclosed in a cast-iron seal pipe 9 inches diameter. This pipe will be formed as a stand pipe, with flanged base and four arched openings at the bottom. The joints will all be socket and spigot made with lead, and all the spigot ends must be turned, and the bottom of sockets machined, so that when pipes are fitted together on end, and on a level base, they will be perfectly perpendicular. The bottom of one socket in each set of seal pipes will be closed in with a web, leaving a hole $5\frac{1}{2}$ inches diameter for pumping pipe to pass through. The top length of each seal pipe will be bolted against the under side of $\frac{7}{8}$ inch cover to pipe, and a short piece of similar section will be bolted on the upper side, finishing with a flange and cover. The stand pipes will be held by the same bolts that attach the wrought-iron pipes. The pump levers will not be as shown on Drawing No. 92A, but must be counterbalanced ones. There will be 15 wall ties of 6 inch by $\frac{3}{8}$ inch wrought iron running right round the tank, built into the wall. These ties will be jointed as shown on Drawing No. 91, and made in lengths of not less than 15 feet, and not more than 30 feet.

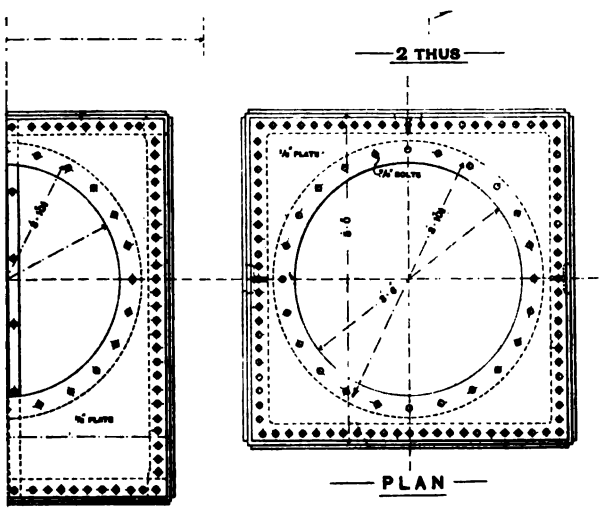
"There will be six cast-iron overflow pipes 8 inches by 6 inches, of the form and sizes shown on Drawing No. 91. There will be six holding-down bolts $2\frac{1}{2}$ inches diameter to each of the 26 standards. The distance from face of stone under standard to head of bolt, when fixed, will be 16 feet. There will be six anchor plates to each standard of 9 inches by 1 inch plate, with $2\frac{1}{2}$ inch square holes for the bolts,

DRAWING No. 90.

DETAILS OF BORINGS.

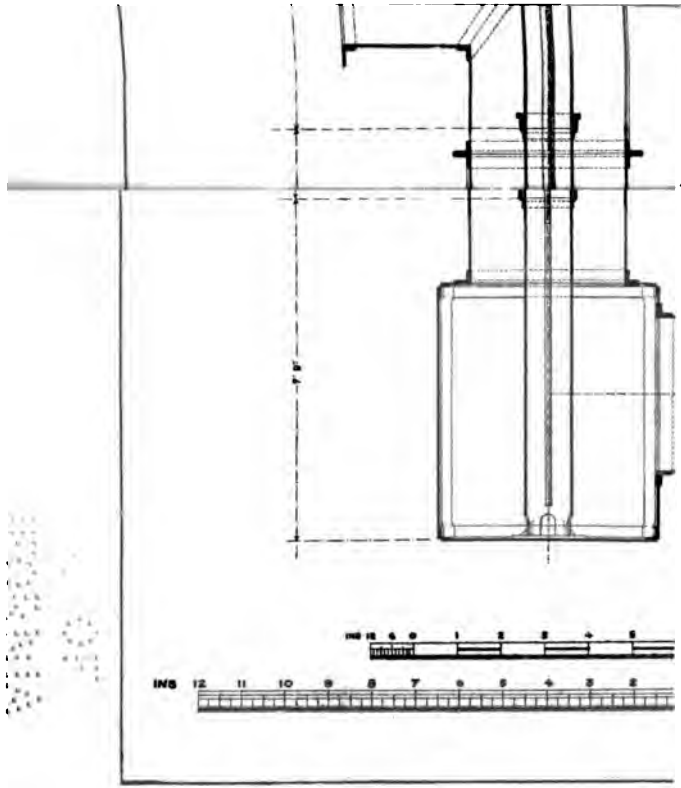
COPING STONE OF TANK 104·13 ABOVE TYNE DATUM.



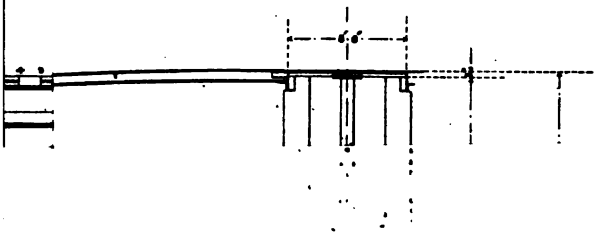


ELSWICK GAS WORKS.

W. Craig Litt.
Engineer


INS 12 11 10 9 8 7 6 5 4 3 2

DRAWING No. 93.



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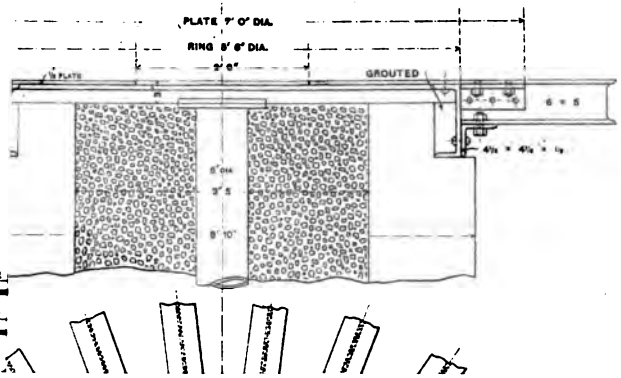
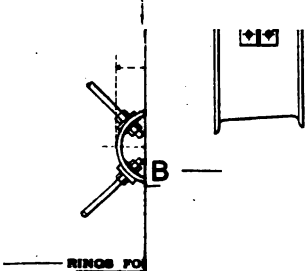




ELSWICK GAS WORKS,

W. Craig Litt.
Engineer.

PHOTO-LITHO. SPRAGUE & Co. Ltd. 4 & 5, EAST HARDING STREET, FETTER LANE, E.C.

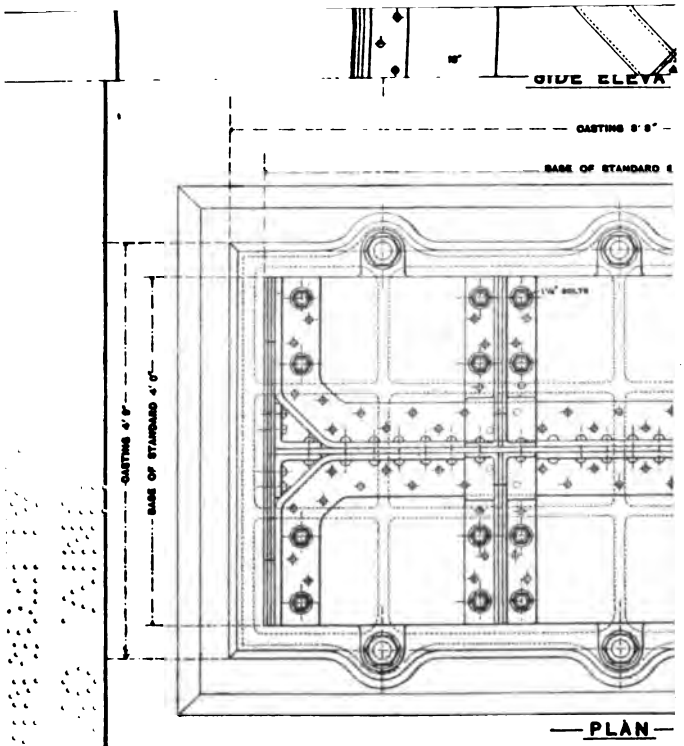
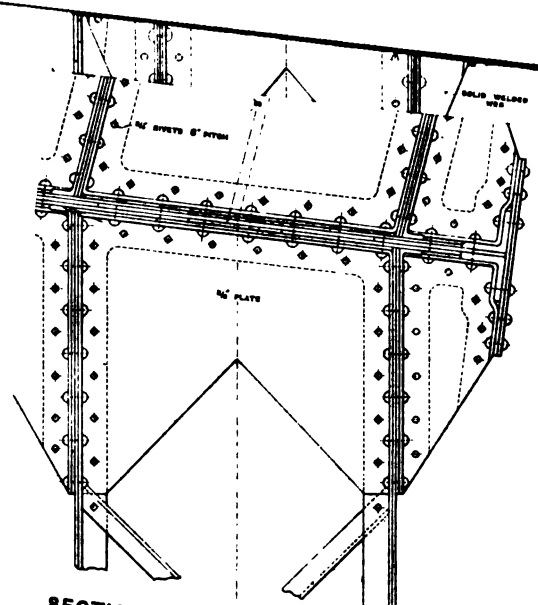


PHOTO-LITHO. SPRAGUE & Co. Ltd. 4 & 5, EAST HARDING STREET, FETTER LANE, E.C.

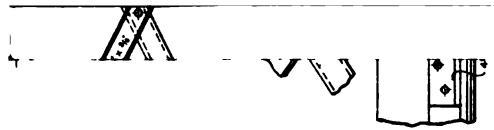


SECTION ON LINE C-C
LOOKING DOWN.

ELSWICK GAS WORKS.

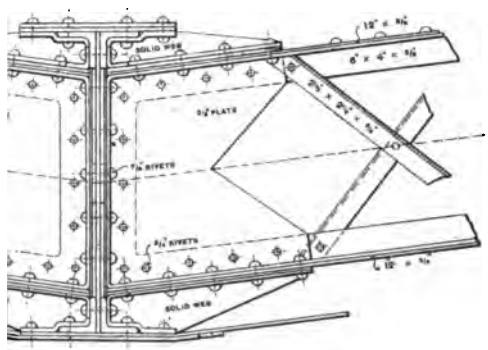
W. Craig Gibb
Engineer.

PHOTO-LITHO SPRAGUE & Co. Ltd 4 & 5, EAST HARDING STREET, FETTER LANE, E.C.



LEVATION —— —— SIDE ELEVATION ——

8TH GIRDER.



TION ON LINE B B ——

ELSWICK GAS WORKS,

W. Craig Gill
Engineer.

OTO-LITHO. SPRAGUE & Co L^TD 4 & 5, EAST HARDING STREET, FETTER LANE, E.C.

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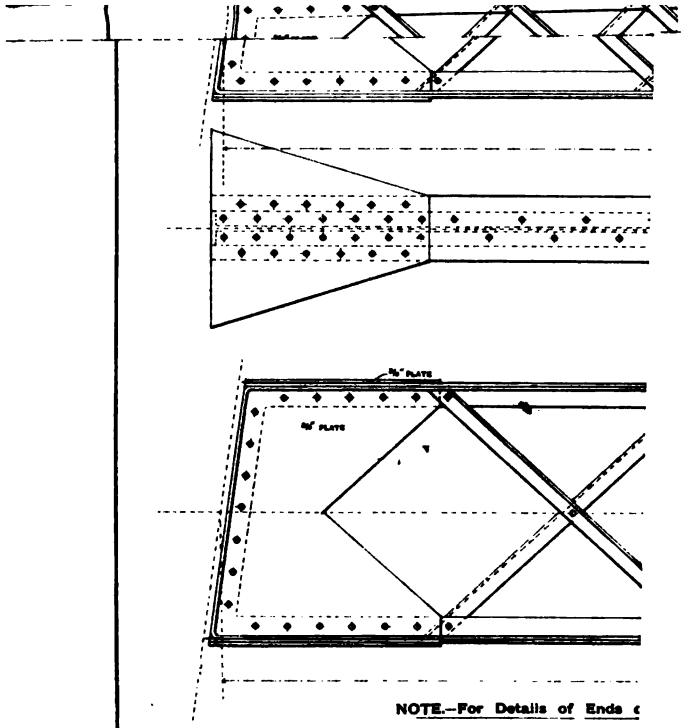

NOTE.—For Details of Ends c

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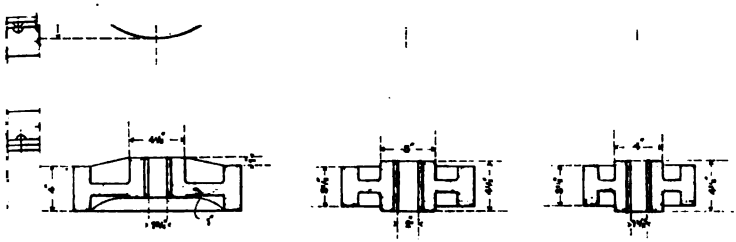
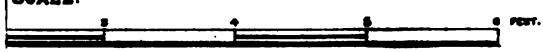


OF ROLLERS.

SCALE.



ELSWICK GAS WORKS,

W. Grig Gill
Engineer.

PHOTO-LITHO, SPRAGUE & Co LTD 4 & 5, EAST HARDING STREET, FETTER LANE, E.C.

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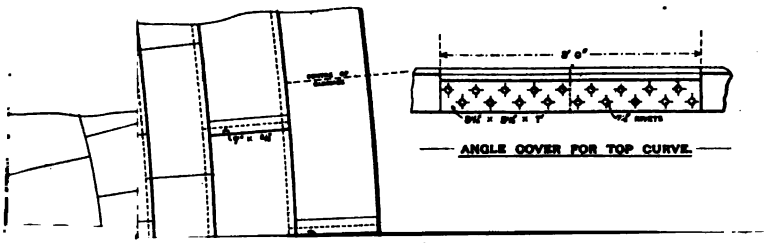
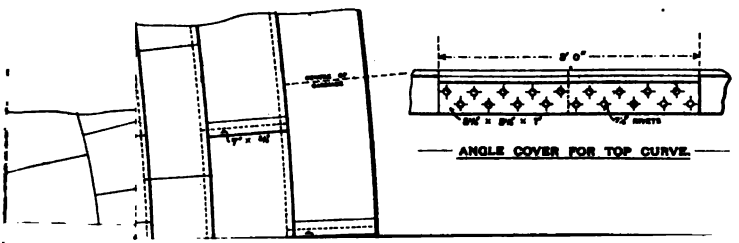
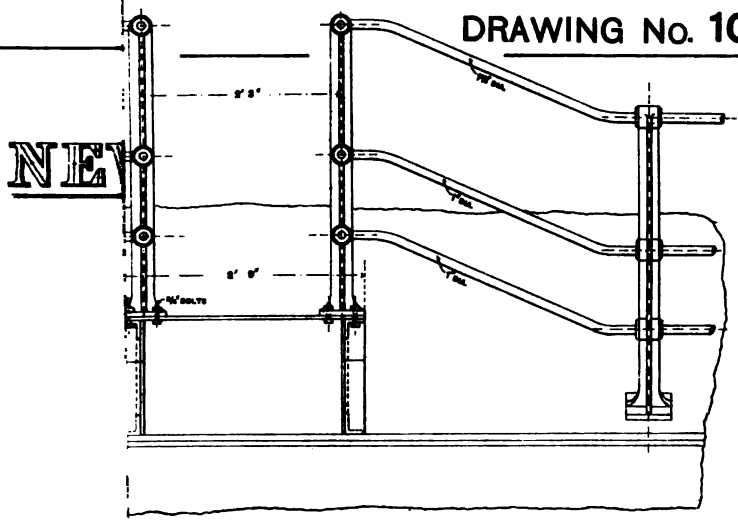
DRAWING No. 101.



DRAWING No. 101.



DRAWING No. 102.



ING PLATFORM ON INNER LIFT

which will have square necks $2\frac{1}{2}$ inches long, and 5 inch square heads forged solid on the shanks. The crown framing as shown on Drawings Nos. 93, 94 and 95, will be composed of rolled steel joists and tee steel stays, with wrought-iron diagonal bracing. There will be four rings of standards. The outer ring will consist of 52 rolled steel joists 12 inches by 5 inches by 32 lbs. per foot, each in one length without joint, fitted with base plates and ears as shown and braced together, with two sets of tie rods $\frac{7}{8}$ inch diameter, wrought iron. The second ring will consist of 52 rolled steel joists 12 inches by 5 inches by 32 lbs. per foot, similar to the outer row in fittings and bracing. The third ring will consist of 26 rolled steel joists 12 inches by 5 inches by 32 lbs. per foot, similar to the outer row in fittings, but having only one set of bracing. The centre ring will consist of 26 rolled steel joists 10 inches by 5 inches by 29 lbs. per foot, fitted with shoes and ears, and braced together with two sets of $\frac{7}{8}$ inch wrought-iron tie rods. The different rings of standards will also be tied together radially with diagonal bracing 1 inch diameter. There will be four lewis bolts, 1 inch diameter, let 7 inches into concrete for each upright standard. There will be 26 main radial joists running from the centre ring to the outer line. These joists will be 6 inches by 5 inches by $\frac{7}{16}$ inch by 25 lbs. per foot run, and will break joint in all cases over the upright standards. There will also be 26 intermediate radial joists 6 inches by 5 inches by 25 lbs., running from the third row of columns to the outer line. These joists will also break joint over upright standards, and the inner ends will be cut and fitted into the purlin joists of the third line. These radial joists must all be bent and set to the true curve of gasholder crown. There will be four rows of main purlins running right round the framing at the same centre line as the uprights. These purlins will be all formed of rolled steel joists, 6 inches by 5 inches by $\frac{7}{16}$ inch by 25 lbs. per foot. The two outer rings and the centre ring will be cut square and straight, but the third ring will be set to the true radius. All the purlins will be cut and fitted into the radial joists, and connected to them by means of $\frac{3}{8}$ inch plates. These plates will also form the cover plates for the joints in radial joists. The upright standards will be further attached to radial joists by means of tee bar struts 5 inches by 4 inches by $\frac{3}{8}$ inch, and to purlins by tee bar struts 5 inches by 3 inches by $\frac{3}{8}$ inch. The radial joists will all be bound together in the centre by a welded ring of steel channel 10 inches by $3\frac{1}{2}$ inches by $\frac{1}{2}$ inch, and 5 ft. 6 in. diameter outside. The top flange of 6 inch by 5 inch radial joists will be cut away, and a circular $\frac{1}{2}$ inch plate 7 feet diameter will be riveted to the channel and attached to the joists by means of angle knees $3\frac{1}{2}$ inches by 3 inches by $\frac{1}{2}$ inch, so that the plates and top flange of joists are all

level. The 6 inch by 5 inch joists will be carried underneath by a welded ring of angle steel 4½ inches by 4½ inches by ½ inch riveted to channel ring. There will also be two other rings on the centre post composed of channel steel 6 inches by 3 inches by ½ inch by 19 lbs. per foot, welded solid; the upper ring will be 5 ft. 10 in. diameter inside, and the lower ring 6 ft. 8 in. diameter inside. Each of these rings will have 13 lugs of tee steel, 5 inches by 4 inches by ⅜ inch by 6 inches long, riveted on with four rivets, to take the double eyes of bracing ties. After the lower ring is fixed in position, a welded ring of angle iron 4 inches by 3 inches by ½ inch will be lowered down on to it, and fixed to the wall by 13 lewis bolts 1 inch diameter, let 5 inches into wall and run with lead. There will be 26 standards in guide framing, composed of plates, angles, channels, tees, &c., as shown on Drawings Nos. 96, 97 and 98. These standards will rest on cast-iron bases, 8 ft. 8 in. by 4 feet by 10½ inches high. The metal in bases will be 1½ inch thick, and there will be two longitudinal and three cross ribs to each base, 1½ inch thick, and the full depth of the base. There will be six bosses to each standard base, with 3 inch diameter holes cast in for the 2½ inch holding-down bolts. The bases must be in one piece, and must be faced entirely over both top and bottom bearing surfaces in a planing machine. There will be 24 holes for 1½ inch bolts through top of each base. The standards will be 8 feet deep at the bottom and 2 ft. 6 in. deep at the top, and will measure 134 ft. 7½ in. over all when finished. The base plates will be 8 feet by 4 feet by ¾ inch; the main angles will be 6 inches by 6 inches by ⅝ inch for a distance of about 82 feet from the base, and 5 inches by 5 inches by ½ inch from there to the top; the covers to 6 inch by 6 inch by ⅝ inch angles will be 5¼ inches by 5¼ inches by ¾ inch, and to 5 inch by 5 inch by ½ inch angles, 4½ inches by 4½ inches by ⅝ inch, and the angles must break joint with one another in all cases. The bottom web will be 5 feet deep and ½ inch thick and the full width of the standard, and will be attached to the base-plate by means of two 6 inch by 6 inch by ⅝ inch angles joggled over the vertical angles. There will also be two gussets on each side of bottom web, of ½ inch plate, and 4½ inch by 4 inch by ½ inch angles, riveted to web and base plate. The webs on back and front of standard will be 18 inches by ½ inch from the base to the third girder, and 12 inches by ½ inch from there to the top. There will be a cross web at the centre of each line of girders, ½ inch thick. The first and second webs from the bottom will be 3 feet deep, the third and fourth 2 feet deep, and the fifth 1 ft. 6 in. deep. These cross webs will each be attached to the main webs by means of large covers of the different sizes shown, and ¼ inch thick. There will be no cross web at the sixth girder, but

instead, two $\frac{3}{8}$ inch cover plates, riveted to the 12 inch by $\frac{1}{2}$ inch vertical webs at each side, and of the depth shown on Drawing No. 98. The flanges will be 4 feet wide at the base, and will taper in a sweep to 2 ft. 6 in. wide, at a point 8 feet from the base. From this point there will be a straight taper to the top, which will be 1 ft. 6 in. wide. There will be three plates on the back of standard, two $\frac{3}{8}$ inch thick, and one $\frac{1}{2}$ inch thick. The first $\frac{3}{8}$ inch plate will stop about 78 feet from the bottom, and the second $\frac{3}{8}$ inch plate about 102 feet from the bottom. The $\frac{1}{2}$ inch plate will run right through. There will be two plates on the front of standard, $\frac{1}{2}$ inch thick. They will both run the full height, and will taper in the same manner as the back plates. The front and back plates must all break joint with one another, except at the bottom, and all joints on the same side must be at least $10\frac{1}{2}$ inches apart. Wherever more than one plate is joined under one cover, cover strips the full length and same thickness as the cover must be inserted on the inside next the angle. The diagonal bracing of standard will be composed of steel channel bars. Between the base and the first girder the bracing will be 6 inches by 3 inches by $\frac{1}{2}$ inch by 19 lbs. per foot; between the first and second girders, 5 inches by 3 inches by $\frac{1}{2}$ inch by 16 lbs. per foot; between the second and third girders, 5 inches by $2\frac{1}{2}$ inches by $\frac{3}{8}$ inch by 12 lbs. per foot; between the third and fourth, and fourth and fifth girders, 4 inches by $2\frac{1}{2}$ inches by $\frac{3}{8}$ inch by 10 lbs. per foot; between the fifth and sixth girders, 3 inches by $1\frac{1}{2}$ inch by $\frac{3}{8}$ inch by 7·5 lbs. per foot. The channels will all have round wrought-iron packings inserted at their intersection. The front and back members of standards will be further tied together by means of horizontal tee bars, with corner gusset plates. These bars will be as shown on Drawings Nos. 96 and 98, and will be 6 inches by 4 inches by $\frac{5}{8}$ inch in the first bay, with $\frac{1}{2}$ inch gussets; 6 inches by 4 inches by $\frac{1}{2}$ inch in the second bay, with $\frac{1}{2}$ inch gussets; 6 inches by 3 inches by $\frac{1}{2}$ inch in the third and fourth bays, with $\frac{1}{2}$ inch gussets; and 5 inches by 3 inches by $\frac{1}{2}$ inch in the fifth and sixth bays, with $\frac{3}{8}$ inch gussets. The whole of the rivets in main angles, flanges, ends of girders, struts, and all connections at the base will be $\frac{7}{8}$ inch diameter, and of the various pitches shown on Drawings. The remainder of the rivets will be $\frac{3}{4}$ inch diameter. The guide rails up the front of standards will be formed of rolled joists 8 inches by 6 inches by $\frac{1}{2}$ inch by 35 lbs. per foot, secured to the standard by means of cast-steel brackets, as shown on Drawing No. 96. There is only one size of bracket shown on the drawing, but the pattern will have to be altered to suit the 5 inch by 5 inch by $\frac{1}{2}$ inch angles, and also decreasing width of flange plates. The bottom of guide rail will be secured by a small steel casting, fastened to base plate with studs,

and shaped to fit the joist. The brackets will each be riveted to the standard with four 1 inch diameter rivets, and the guide rail bolted to them with 1 inch bolts, countersunk on the face. There will be six rows of girders between the standards, the five lower rows placed horizontally, and the sixth row placed upright. The five horizontal girders will all be exactly similar in design, with solid welded tee-steel frames 6 inches by 4 inches by $\frac{3}{8}$ inch, and 12 inch by $\frac{3}{8}$ inch, flange plates; the end webs will be cut out to line with the angle of the lattices, and gussets will be inserted at the back and front to connect them to the flanges of standards. These gussets will be of 6 inch by 4 inch by $\frac{3}{8}$ inch tee steel, with $\frac{3}{8}$ inch plate webs for the lower girders, but in the case of the upper girders, where the gussets are very narrow, the web of the tee will be welded up solid.

"The widths of the girders will be as follows:—

1st row	4 ft. 0 in. over all.
2nd row	3 ft. 7½ in. „
3rd row	3 ft. 3 in. „
4th row	2 ft. 10½ in. „
5th row	2 ft. 6 in. „

"The sixth or top row of girders will be 3 feet deep over all and placed upright. They will be formed of 6 inch by 4 inch by ½ inch tee steel welded frames, 9 inch by $\frac{3}{8}$ inch flanges, and 2¾ inch by 2¾ inch by ½ inch angle lattices. The end webs will be $\frac{3}{8}$ inch thick, cut out to line with the lattices. There will also be $\frac{3}{8}$ inch taper plates on the top and bottom at the ends, riveted to the flanges and to 4 inch by 4 inch by ½ inch angles on the standard. The rivets through the girder ends will all be $\frac{7}{8}$ inch diameter, and the remainder of the rivets ¾ inch diameter. For details of girders generally see Drawing No. 99, and for details of ends and attachments to standard see Drawings Nos. 96, 97 and 98. The standards will be braced together by means of diagonal bars between the rows of girders. These bracing bars will be composed of steel flats riveted to shaped plates on the standard backs, and secured at the crossing by a single plate riveted to both bars. The bottom tiers will consist of 8 inch by ¾ inch bars, with ¾ inch plates; the second tier of 7½ inch by ¾ inch bars, with ¾ inch plates; the third tier of 7 inch by $\frac{5}{8}$ inch bars, with $\frac{5}{8}$ inch plates; the fourth tier of 6½ inch by $\frac{5}{8}$ inch bars, with $\frac{5}{8}$ inch plates; the fifth tier of 6 inch by $\frac{5}{8}$ inch bars, with $\frac{5}{8}$ inch plates; the sixth tier of 5 inch by $\frac{5}{8}$ inch bars, with $\frac{5}{8}$ inch plates. The plates on standards must be carefully cut to shape and set to the true angle, and both end and centre plates must have the edges dressed off neatly and smoothly. The whole of the rivets used in connection with these diagonal ties must be $\frac{7}{8}$ inch diameter. Suit-

able packing plates must be inserted in standards and girders wherever necessary, and the edges must in all cases finish true with those of the members to which they are attached, and must be left smooth.

"There will be a ladder fixed in position shown on Drawing No. 102, and reaching from the level of coping to the top of the sixth girder. The sides will be composed of 3½ inch by ⅝ inch round-edged flats, and the rungs of ¾ inch round iron, properly shouldered and riveted on the outside, the heads being knocked closely down and left smooth. The ladder will be 11 inches wide inside, and the rungs 10 inch pitch. The bottom ends of the ladder will be let 6 inches into the stone and run with lead, and the top bent over, welded, and attached to a bracket of 3½ inch by 3½ inch by ⅜ inch angle steel fixed on the top of the sixth girder. There will be a small platform on each of the five lower girders, composed of $\frac{5}{16}$ inch chequer plate, secured to the girder flanges by means of 3 inch by 3 inch by ⅜ inch angles, the inside angle of each being bent round to form an attachment for the ladder, and strengthened by a back stay of similar section. There will be four cast-iron handrail standards to each platform, with three lines of wrought iron tube handrail, the top 1¼ inch diameter, and the two lower lines 1 inch diameter. The standards will be of cross form in section, of ⅝ inch metal, with round bosses, and 6 inch square bases ¾ inch thick. The projecting ends of tube will be finished off with neat caps of wrought iron, screwed in and rounded off. There will be three lines of handrail of similar section round the crown of the gasholder. The standards will be of the same pattern as those for platforms, but will have bases set to the curve of crown, and will be about 5 ft. 6 in. apart. The ends of tubes will also be plugged as before specified. There will be a landing platform on crown opposite the ladder, consisting of two cantilevers of ⅜ inch plate, and 2½ inch by 2½ inch by ½ inch angle frames, with $\frac{5}{16}$ inch chequered platform. The handrail of crown will be returned on to the platform on each side, as shown. Except where otherwise specified, the gasholder and guide framing will be constructed throughout of Siemens-Martin mild steel, capable of sustaining a tensile strain of from 28 to 32 tons per square inch of section, with an elongation of 20 per cent. in 8 inches. The wrought iron used must be of such quality as shall be capable of sustaining a tensile strain of 22 tons per square inch of section, with an elongation of not less than 10 per cent. in 8 inches. The rivet iron must be capable of sustaining a tensile strain of 26 tons per square inch of section, with an elongation of not less than 12 per cent. in 8 inches. The rolled joists and channels must all be of English manufacture, as no foreign material of any description will be allowed to be used. The whole of the cast iron shall be of the best quality,

and the castings must be clean and sharp, and free from flaws, sand-holes, airholes, cold shuts, or any admixture of cinder or dirt. Castings that are broken, warped, or uneven in thickness, will not be accepted, and the surface of all castings when finished must be free from sand. The quality of cast iron used must be such that a bar 2 inches by 1 inch and 3 ft. 6 in. long, when supported at points 3 feet apart and loaded in the centre, shall sustain a weight of not less than 28 cwt. for a period of twenty-four hours. The whole of the cast and wrought ironwork and steel must receive one coat of hot boiled linseed oil before leaving the manufacturer's yard, and one coat of red oxide paint before erection. After erection the whole of the work must receive two coats of paint of such varied colours as the engineer may direct. All holes in plates, bars, angles, and tees, both in gasholder and guide framing, are to be drilled, and holes in sheeting punched. All edges of plates, and abutting ends of all parts, are to be planed or otherwise machined. Drifting will on no account be allowed. All riveting, as far as practicable, to be done by machine. All rivets above $\frac{3}{8}$ inch diameter must be put in hot, and rivets must be countersunk wherever necessary, whether specified or not. All cover plates must have such number of rivets on each side of the joint as will give a section equal to the section of the member covered at the joint. Before riveting together the plates and sheets, the joints of each must be well painted with red lead paint, and a broad tape, saturated with oil and red lead, inserted. On the completion of the gasholder, the inlet and outlet pipes shall be filled with water, and the gasholder raised to its full height with atmospheric air not less than three times, to test the working of the guide carriages. It must then be raised to the full height, and remain under test for not less than three days, to test the soundness of the joints. When all defects (if any) have been made good, the gasholder must be filled with gas, and finally tested for a period of twenty-four hours."

ABSTRACTS OF PAPERS PUBLISHED IN VARIOUS CHEMICAL JOURNALS.

New Filling Material for Reaction Towers. By OSCAR GUTTMANN. (Jour. Soc. Chem. Industry, xvii. 1898, 994.)

Small hollow balls are used, having six depressions, with a small hole at the bottom of each depression. Gases passing up a tower filled with these balls not only come into contact with liquid flowing over the outer surface, but also with that pocketed in the interior of the balls.

The absorbing surface is said to be 2¼ times as great as that of a coke tower, and 2½ times that of a plate tower.—E. L. P.

Some Chemical Properties of Scotch Coal. By W. CARRICK ANDERSON and JAMES ROBERTS. (Jour. Soc. Chem. Industry, xvii. 1898, 1013.)

A thorough and complete knowledge of the composition of coal is of great importance, the output for the United Kingdom in 1897 being 200 millions of tons, and for the United States of America, 190 millions.

The author points out that if the whole of the output were carbonised and the ammonia recovered, as in gasworks at the present time, notwithstanding the fact that but a small percentage of the nitrogen of the coal is thus obtained, much would be done towards meeting the want of nitrogenous manures, which, in the opinion of Sir William Crookes, is likely to be a problem of universal importance in the not distant future. Whilst if the whole of the nitrogen contained in the United Kingdom output of 200 million tons of coal could be utilised, it would be equivalent to nearly 9½ million tons of sulphate of ammonia per annum. Though much has been done in improving methods of carbonisation and combustion, much still remains to be done. The difficulties, however, are very great, not only owing to the fact that the material is of infinitely varying composition, and therefore requiring varying treatment, but also that even where coals are of practically identical composition, their properties may be entirely different.

It appears necessary, therefore, to endeavour to obtain a clear conception of what coals are, and what it is that causes them to possess different properties, even when of the same composition.

With this end in view, details of experiments embodied in the following tables are given, which have been made by the authors upon typical coals of the west central coal field of Scotland. The numbers in the tables indicate the relative geological position of the coals, No. 1 being in the upper strata and No. 15 in the lowest.

I. Proximate Analyses of Coals.

—	Upper Coal Measures.												Carboniferous Limestone Measures.		
	Hamilton District.					Airdrie District.						Slamannan.			
	1 Ell.	2 Main.	3 Splint.	4 Gas.	5 Virgin.	6 Virtue-well.	7 Kiltongue.	8 Upper Drumgray. I.	9 Upper Drumgray. II.	10 Lower Drumgray. I.	11 Lower Drum-gray. II.	12 Lower Drumgray. III.	13 Kilsyth Haughrigg.	14 Bannock-burn Main.	15 Kilsyth Coking.
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Moisture	9·99	9·09	7·27	5·56	7·77	6·90	10·45	4·70	3·82	7·14	4·02	1·83	1·98	1·75	1·72
Ash	0·98	1·28	2·20	3·70	2·30	5·79	1·39	3·12	2·81	1·57	2·01	4·00	2·95	2·75	2·01
Volatile matter	33·33	35·84	36·22	38·25	33·53	37·73	35·25	40·27	35·83	36·78	33·81	20·61	32·55	27·40	28·45
Fixed carbon	55·70	53·79	54·31	52·49	56·40	49·58	52·91	51·91	57·54	54·51	60·16	73·56	62·52	68·10	67·82
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

II. Ultimate Analyses of Dry Organic Matter (i.e. Coal less Ash and Moisture).

—	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Hydrogen	5·07	5·56	5·32	6·11	5·67	5·70	6·09	6·16	5·00	5·48	5·32	4·64	5·32	5·38	5·40
Carbon	80·74	82·13	83·41	83·92	83·03	82·30	83·16	83·69	82·73	82·10	82·26	89·06	84·86	86·70	84·67
Oxygen (and organic sulphur)	12·47	10·59	9·62	8·29	9·59	10·08	8·88	8·36	10·26	10·83	10·40	4·05	7·89	5·94	7·82
Nitrogen	1·72	1·72	1·65	1·68	1·71	1·92	1·87	1·79	2·01	1·59	2·02	2·25	1·93	1·98	2·11
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

III. Specific Gravity and Calorific Power.

—	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Specific gravities	1·266	1·261	1·292	1·290	1·286	1·322	1·275	1·308	1·305	1·279	1·289	1·322	1·291	1·306	1·275
Calorific power (Thompson's calorimeter)	7,480	7,590	7,425	7,370	7,480	6,957	6,930	7,507	7,370	7,177	7,508	7,810	7,535	7,865	7,610

—	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Caking index . .	4 +	4	3·5	3·5 −	4	4	4	4 −	6·5	4·5 +	6·5 +	0	9 +	15·5	16 +

V. Losses at 300° C. in a Current of Dry CO_2 for 3 Hours.

—	1	2	3	4	5	6	7	8	9	10	11	—	13	14	15
Percentage loss of dry coal at 300° C. . .	9·5	16·2	16·2	21·8	17·7	16·2	11·9	14·7	8·1	12·6	7·9	—	13·1	7·3	6·4
Physical condition of residue.	A considerable part formed a dull earthy coke, the rest in powder.	Residue just cohered, and no more.						Residue cohered slightly, but more than the preceding.	Residue coked and fairly hard in the lower part of the crucible.	Residue cohered, but no more.	Residues dull, but fairly strong, hard cokes.			Dull, but good, hard, strong cokes.	

VI. Composition of Acid Bodies got by Oxidation of Coal with Nitric Acid.

—	1	—	3	4	5	—	—	—	—	—	—	12	—	14	15
	per cent.		per cent.	per cent.	per cent.							per cent.		per cent.	per cent.
Hydrogen . . .	3·15	..	3·20	3·17	2·74	..	..	..	..	..	..	2·96	..	3·33	3·16
Carbon	58·45	..	62·31	61·35	58·97	..	..	..	..	..	..	63·35	..	62·64	61·32
Oxygen	32·36	..	28·04	29·16	32·67	..	..	..	..	..	..	28·00	..	28·55	30·80
Nitrogen . . .	4·79	..	4·79	4·71	4·00	..	..	..	..	..	..	4·27	..	4·42	3·30
Sulphur	0·72	..	0·31	0·68	0·27	..	..	..	..	..	..	0·51	..	0·43	0·73
Ash	0·53	..	1·35	0·93	1·35	..	..	..	..	..	..	0·91	..	0·63	0·69
	100·00	..	100·00	100·00	100·00	..	..	..	..	..	..	100·00	..	100·00	100·00

VII. Composition of Organic Matter in above Acids.

—	1	—	3	4	5	—	—	—	—	—	—	12	—	14	15
	per cent.		per cent.	per cent.	per cent.							per cent.		per cent.	per cent.
Hydrogen . . .	3·17	..	3·24	3·20	2·78	..	..	..	..	..	..	2·99	..	3·35	3·18
Carbon	58·76	..	63·17	61·93	59·78	..	..	..	..	..	..	63·93	..	63·05	61·75
Oxygen	32·53	..	28·42	29·43	33·11	..	..	..	..	..	..	28·25	..	28·72	31·01
Nitrogen . . .	4·82	..	4·85	4·75	4·05	..	..	..	..	..	..	4·31	..	4·45	3·32
Sulphur	0·72	..	0·32	0·69	0·28	..	..	..	..	..	..	0·52	..	0·43	0·74
	100·00	..	100·00	100·00	100·00	..	..	..	..	..	..	100·00	..	100·00	100·00

In Table II. the close agreement in the composition of some of the coals from strata of different geological age is striking—for example, Nos. 2 and 11, 4 and 8, and 13 and 15—and appears to support Baltzer's theory that "coals are essentially mixtures of complex carbon compounds, which form a genetic and probably homologous series of complex structure analogous to that of the aromatic series."

That coals of the same composition may have widely different properties is shown in Table I., from which it will be seen that the amount of coke obtained from the coals previously referred to as having the same composition, is dissimilar.

It will also be seen from Table IV.—in which the numbers given as the caking indices roughly represent the relative coherence of the cokes produced—that the most valuable coking coals are from the lowest strata, and that coals from the intermediate strata are better in this respect than those from the uppermost strata. No 12 is an anthracitic coal formed by the intrusion of volcanic rock.

It has been shown in a previous paper that the formation of coherent residues by the coals of the uppermost strata, is due to the presence of some saponifiable constituent which could be removed by boiling the coals in a 5 per cent. solution of caustic potash for an hour or two; that the property of caking exhibited by the coals of the limestone series was not so removed; and that in the intermediate series a state of things existed which formed a connecting link between these extremes. In the intermediate series, therefore, with the exception of Kiltongue (No. 7) there appears to be present to a greater or lesser degree some non-saponifiable constituent capable of causing the residue to cohere to a certain extent, although short of that exhibited in the case of the coals of the lowest series. To ascertain whether this was caused by differences in quantity of this non-saponifiable binding material, or whether the material differed in the several coals, the experiments detailed in Table V. were made.

From the results obtained it is apparent that in the upper series the cohesion of the residues is due to the rapid breakdown upon ignition of resinous matter which may be volatilised at 300° C. The residue of the Virtuewell (No. 6), however, owes its tendency to cohere to a non-saponifiable substance which is volatilised on heating the coal for three hours at 300° C.

The Upper Drumgray (No. 8) and Lower Drumgray (No. 10) owe the cohesion of their residues partly to non-resinous, but chiefly to volatile resinous and saponifiable bodies; whilst in the cases of the Upper and Lower Drumgray (Nos. 9 and 11) this is due partly to resinous, but chiefly to non-resinous non-saponifiable bodies not volatilised at 300° C.

In the coals of the limestone series—excellent coking coals—the cohesion of the ignited residues is almost entirely due to the breakdown of non-saponifiable bodies. One is therefore enabled to distinguish between a good and bad coking coal by the results obtained on treatment with caustic potash solution.

An endeavour was made to ascertain whether the caking or non-caking of residues upon ignition was due to the constitution of the coal as a whole, or to the presence of some constituent or constituents. Some of the coals were oxidised by boiling with dilute nitric acid, and the resultant "coal acid"

analysed, Table VI. It was found that so long as excess of acid was used, the product obtained with any one coal was invariably of the same composition.

The oxidation bodies obtained, though differing from each other, show no distinct division between the different classes of coal experimented upon.

Are these acid bodies the result of the oxidation of the coal as a whole, or are they the products of the oxidation of a constituent of the coal? If the former, then the formula which will represent coal must be made up of H, O, C, N and S; and if the latter, then the constituent must be of this composition, and the coal itself must be a mixture of this constituent and of others of a different composition.

Ell coal (No. 1) when heated for four hours in a current of dry CO_2, lost 9·5 per cent. of its weight; but the remainder, when oxidised with nitric acid formed a "coal acid" of the same composition which the Ell coal gave before heating. It therefore appears probable that the coal possesses a constituent whose molecule contains nitrogen and sulphur, and from which the "coal acid" is produced, together with a constituent or constituents which break down or distil over at a temperature of 300° C.

From the close resemblance in the acid bodies got from caking and non-caking coals, the authors are of opinion that the difference in the coals themselves is due to the presence of apparently nitrogen-free constituents of the coal, the greater or less ease with which such constituents are volatilised and decomposed giving rise to the non-caking or caking property.

Coals would therefore appear to be made up of (1) a small but fairly constant quantity of resinous matter whose composition does not differ greatly from that of ordinary pine resin, C = 80·7 per cent., H = 9·5 per cent., and O = 9·8 per cent.; (2) an apparently nitrogen-free constituent more or less volatile; and (3) of a complex compound, the molecule of which is rich in nitrogen and also contains sulphur, and which originates from the proteid substances in the vegetation from which the coal has been derived.—E. L. P.

Preliminary Report of the Committee on Coal Analysis. (From the Journal of the American Chemical Society. Chem. News, lxxviii. 1898, 75.)

The Committee of the American Chemical Society appointed to consider the adoption of uniform methods for the proximate analysis of coal submit the following outline of methods of analysis, and at the same time appeal to all chemists interested in the matter for information and criticism of the methods proposed, in order that the conclusions finally arrived at may be representative of general experience.

Methods of Analysis.

1. *Sampling.*—At least five pounds of coal should be taken for the original sample, with care to secure pieces that represent the average. These should be broken up and quartered down to obtain the smaller sample, which is to be reduced to a fine powder for analysis. The quartering and grinding should be carried out as rapidly as possible, and immediately after the original

sample is taken, to prevent gain or loss of moisture. The powdered coal should be kept in a tightly stoppered tube or bottle till analysed.

2. *Moisture.*—Dry 1 grm. of the coal in an open porcelain or platinum crucible at 104°–107° for one hour—best in a double-walled bath containing pure toluene. Cool in a desiccator and weigh covered.

Experiments made by Dr. Hillebrand show that higher and probably more accurate results are obtained by drying the coal in vacuo over sulphuric acid for 20 hours, or in air over sulphuric acid for five days. Experiments made by Mr. W. E. Burk show that the loss of volatile matter other than water from coal heated to 100° C. in a current of dry air is inconsiderable.

3. *Volatile Combustible Matter.*—Place one grm. of fresh undried coal in a platinum crucible weighing 20 to 30 grms., and having a tightly fitting cover. Heat over the full flame of a Bunsen burner for seven minutes. The crucible should be supported on a platinum triangle with the bottom 6 to 8 cm. above the top of the burner. The flame used should be 20 to 25 cm. high when burning free, and the determination made in a place free from draughts. The upper surface of the cover should burn clear, but the under surface should remain covered with carbon. To find volatile combustible matter subtract the per cent. of moisture from the loss found here.

4. *Ash.*—Burn the portion of coal used for the determination of moisture at first over a very low flame, with the crucible open and inclined, till free from carbon. If properly treated, this sample can be burned much more quickly than the dense carbon left from the determination of volatile matter.

5. *Fixed Carbon.*—This is found by subtracting the per cent. of ash from the per cent. of coke as found in paragraph 3.

6. *Sulphur.*—The Committee desire information of any comparative results obtained with Eschka's method (with sodium or potassium carbonate), Carius's or others.

A Scheme for the Rapid Analysis of Boiler Waters for Scale-forming Ingredients. By THOS. B. STILLMAN. (Chem. News, lxxviii. 1898, 319.)

The following method for determining the total scale-forming matter present in a feed water, is in use in many railroad laboratories.

Half a litre of the water is evaporated to dryness in a weighed platinum dish. The residue is then treated with a 50 per cent. mixture of alcohol with water and filtered, the undissolved matter being taken as scale-forming material.

This method, however, does not differentiate between the scale formed by the carbonates, which is easy of removal, and that of calcium sulphate, which is hard and compact and removed with difficulty.

The following scheme of analysis is therefore recommended :—

Scheme for Rapid Analysis of Boiler Waters.

(Communicated to the writer by Prof. Wm. Main, Chemical Expert to New York Filter Co.)

Total solids. Mineral matter. Organic matter.	The desired amount of water is evaporated to dryness in a platinum dish and weighed; this residue (1) represents total solids. Ignite, then moisten slightly with distilled water, place in an atmosphere of carbonic acid for half an hour, dry and weigh; this residue (2) is the total mineral matter combined with carbonic acid, as it previously existed, before ignition. The difference in weight between Residue 1 and Residue 2 is the organic matter.
Scale-forming ingredients.	Extract soluble matter from Residue 2 with successive small portions of distilled water, in all 50 c.c. or less. Filter through ashless filter; dry the residue adhering to platinum dish. Dry and ignite filter, and return the matter it may have retained to the platinum dish and weigh. The weight of this residue (3) represents the total scale-forming ingredients of the water.
Non-scale-forming ingredients.	The filtrate contains the alkalis and magnesia combined with sulphuric acid and chlorine. These may be determined if desired, but are not necessary in this operation. Their aggregate weight may be determined by subtracting Residue 3 from Residue 2.

Treat Residue 3 with hot HCL and filter. Wash well.

Residue. Insoluble mineral matter. Dry, ignite, and weigh as such. SiO_2, &c.	Filtrate.—Add ammonic hydrate in slight excess, boil, and filter.			
	Residue. Al_2O_3, Fe_2O_3. Dry, ignite, and weigh as such.	Filtrate.—Add solution of ammonic oxalate in slight excess. Set aside half an hour. Wash with water containing one-eighth its volume of ammonic hydrate.		
		Residue. Dry, ignite, and weigh as CaO.	Filtrate.—Add solution of sodic phosphate with constant stirring. Set aside half an hour, filter, wash with water containing one-eighth its volume of ammonic hydrate.	
			Residue. Dry, ignite, and weigh as $Mg_2P_2O_7$, and calculate to MgO.	Filtrate.—Acidify with HCL, add solution of $BaCl_2$ in slight excess, boil, set aside for half an hour, filter, wash well with hot water.
				Residue.—$BaSO_4$. Dry, ignite, and weigh as $BaSO_4$, and calculate to SO_3. This amount of SO_3 is combined with CaO to form $CaSO_4$ that exists in Residue 3.
SiO_2, &c.	Al_2O_3, Fe_2O_3.	CaO.	MgO.	SO_3.

[E. L. P.]

The Chemical Composition and Technical Analysis of Water-Gas. By EDWARD H. EARNSHAW. (The American Gas Light Jour. lxix. 1898, 488.)

The oils used in producing carburetted water gas are decomposed in the fixing chamber with the production of hydrogen, gaseous hydro-carbons, naphthalene and benzene and its homologues.

The constituents of coal gas and water gas are the same, but their proportions vary, as is shown by the following representative analyses:—

—	Coal Gas.	Water Gas.
	Per cent.	Per cent.
Benzene vapour	0·50	0·6
Heavy hydrocarbons	4·25	12·8
Carbonic oxide	8·04	30·7
Hydrogen	47·04	32·4
Marsh gas	36·02	13·9
Higher paraffins	0·00	2·4
Carbonic acid	1·60	2·7
Oxygen	0·39	0·7
Nitrogen	2·16	3·8
	100·00	100·0

The heavy hydrocarbons consist chiefly of ethylene and its homologues.

The author states that the presence of the higher paraffins needs primary consideration by the gas analyst, because the methods of analysis usually adopted overlook them. Hempel's methods, so far as the absorbable constituents are concerned, should be followed:—

1. Benzene vapours removed by shaking the gas in explosion pipette over mercury, with 1 c.c. of alcohol previously saturated with the less easily absorbable constituents. The alcohol vapour being afterwards removed by treating the gas with 1 c.c. of water in another explosion pipette.*

2. The carbon dioxide is absorbed by a solution of potassium hydrate.

3. The heavy hydrocarbons by saturated bromine water or by fuming sulphuric acid.

4. Oxygen is absorbed by phosphorus or by an alkaline solution of pyrogallic acid. The author prefers phosphorus, because he is of opinion that a trace at least of oxygen is invariably present, and as the oxygen always gives rise to white fumes when the gas is passed into a pipette containing phosphorus,

* *Note by Abstractor.*—Alcohol will not only absorb hydrocarbous vapours (benzene, &c.), but also variable proportions of the hydrocarbon gases (ethylene, &c.), and the water used for removing the alcohol vapour will also remove a portion of the constituents of the gas. It appears preferable, therefore, to omit this treatment with alcohol, and to rely upon the absorption of the hydrocarbon vapours by fuming sulphuric acid at the same time that the other unsaturated hydrocarbons are absorbed. The objection that the hydrocarbon vapours are partially removed when the gas is treated with caustic potash and pyrogallate of potash, and consequently returned as carbonic acid and oxygen, may be overcome without inaccuracy by omitting the usual agitation of the reagents with the gas (*vide* these Transactions, iv., 1894, 199).

provided the hydrocarbons have previously been removed, the presence of such fumes is a good indication that the hydrocarbons have been completely absorbed.

5. The carbonic oxide is now absorbed by an ammoniacal or hydrochloric acid solution of cuprous chloride. Two pipettes must be used in succession, the last one containing a perfectly fresh solution of cuprous chloride, though even with this precaution a little (about 0·5 per cent.) carbonic oxide is left unabsorbed.

The remaining constituents of the gas, consisting of—

$$(a)\ (H_2) + (CO) + (N_2) + (CH_4) + (C_2H_6) + (C_3H_8),\ \&c.$$

must now be estimated by the method of combustion.

About 14 c.c. of (a) are exploded with about 88 c.c. of air. The contraction in volume is measured, also the diminution in volume upon absorbing with caustic potash the carbonic acid formed, and lastly the residual nitrogen upon absorption of the excess of oxygen. The equations are—

$$(1)\ \text{Contraction in vol.} = \tfrac{3}{2}(H_2) + \tfrac{1}{2}(CO) + 2(CH_4) + 2\tfrac{1}{2}(C_2H_6).$$
$$(2)\ CO_2\ \text{formed}\ \text{,,} = (CO) + (CH_4) + 2(C_2H_6).$$
$$(3)\ \text{Residual nitrogen} = (N_2) + (N_2)^{\text{I}}$$

where $(N)^{\text{I}} = 79·2$ per cent. of the air used for explosion. Consequently the amount of nitrogen in the quantity of gas taken for explosion = residual nitrogen—$(N)^{\text{I}}$.

A second portion of (a) is now mixed with air and passed over heated palladium black. By this treatment the hydrogen and all CO which may be present are burnt, but CH_4 and the higher paraffins are unaffected. The CO_2 formed is then absorbed with caustic potash solution. The equations are—

$$(4)\ \text{Contraction in vol.} = \tfrac{3}{2}(H_2) + \tfrac{1}{2}(CO)$$
$$\therefore\ \text{Hydrogen} = \tfrac{2}{3}(\text{contraction} - \tfrac{1}{2}\,CO).$$
$$(5)\ CO_2\ \text{formed} = CO.$$

If the quantity of gas taken for combustion over palladium was not the same as that taken for explosion, the contraction in volume, and also the CO formed will require to be reduced to the quantity which would have been obtained had the quantity of gas taken been the same. The quantity of CH_4 and C_2H_6 present may then be easily calculated; for, subtracting equation (4) from equation (1), and (5) from (2), gives

$$(x)\ 2(CH_4) + 2\tfrac{1}{2}(C_2H_6)$$

and

$$(y)\ (CH_4) + 2(C_2H_6),$$

calling these differences x and y.

Then (6) $$CH_4 = \frac{4x - 5y}{3}$$

and (7) $$C_2H_6 = \frac{4y - 2x}{3}.$$

The author shows that this method of analysis is correct so far as the *total* volume of paraffins is concerned, even when higher members of the series than Ethane are present. Also that those methods which presuppose the absence

of the higher members of the paraffin series, and the total absorption of CO by cuprous chloride, give erroneous results.

To calculate the heating value of the gas it is necessary to obtain the average composition of the hydrocarbons. Then, from the formula given by Prof. Julius Thomsen * for calculating the heat of combustion of hydrocarbons of the formula CnH_2m :—

$$f = n\,135340 + m\,37780 - a\,14200 + 580$$

in which for the olefin series, CnH_2n—

$$n = m$$
$$a = n - 1,$$

and for the paraffin series, $CnH_2n + 2$,

$$m = n + 1$$
$$a = n - 1,$$

the heat of combustion f may be obtained expressed as calories per molecular weight in grammes.

Translated into English units

B.T.U per cubic foot (olefins) $= n(757) + 70$,

and

B.T.U. „ „ (paraffins) $= n(757) + 251$.

Prof. Julius Thomsen's results translated into English units for the principal constituents of illuminating gas are as under :—

Name.	Molecular Formula.	B.T.U. per Cubic Foot at 60° and 30″.
Hydrogen	H_2	326·2
Carbonic oxide	CO	323·5
Methane	CH_4	1009·0
Ethane	C_2H_6	1764·4
Propane	C_3H_8	2521·0
Butane	C_4H_{10}	3274·0
Ethylene	C_2H_4	1588·0
Propylene	C_3H_6	2347·2
Butylene	C_4H_8	3099·2
Acetylene	C_2H_2	1476·7
Benzene	C_6H_6	3807·4

The results obtained by analysis by the above methods of a sample of 23·5-candle water gas are as under :—

Amount taken for analysis = 100 c.c.
C_6H_6 absorbed by alcohol = 0·4 per cent.
CO_2 „ „ potash = 2·7 „

* Thermo Chemical Investigations, vol. iv., p. 275.

A portion of the residue—12·0 c.c.—was exploded with 87·8 c.c. of air.
1st explosion :—

Contraction in volume	= 16·05 c.c.
CO_2 absorbed by potash	= 10·55 „
Excess O_2 absorbed by phosphorus	= 3·40 „
Illuminants absorbed by bromine	= 11·7 per cent.
Oxygen „ „ phosphorus	= 0·5 „
CO „ „ Cu_2Cl_2	= 31·7 „
Total percentage of absorbable constituents	= 47·0 „
Non-absorbable „	= 53·0 „
	100·0

A portion of the residue now remaining—14·05 c.c.—was exploded with 87·8 c.c. air.
2nd explosion :—

Contraction in volume	= 22·60 c.c.
CO_2 absorbed by potash	= 5·30 „
Excess O_2 „ phosphorus	= 3·80 „
Residual nitrogen	= 70·15 „

A second portion—30 c.c.—was mixed with 70 c.c. air, and the mixture passed over heated palladium black.

Contraction in volume	= 30·40 c.c.
CO_2 absorbed by potash	= 0·40 „

Nitrogen in the 14·05 c.c. of residual gas taken for explosion equals (*vide* Equation 3).

$$70{\cdot}15 - \frac{87{\cdot}8 \times 79{\cdot}2}{100} = 0{\cdot}60 \text{ or } \frac{0{\cdot}60 \times 53}{14{\cdot}05} = 2{\cdot}26 \text{ per cent. in original}$$

gas.

Hydrogen in 30 c.c. equals (*vide* Equation 4).

$$\tfrac{2}{3}(30{\cdot}40 - \tfrac{1}{2}\,0{\cdot}40) = 20{\cdot}13 \text{ or } \frac{20{\cdot}13 \times 53}{30} = 35{\cdot}56 \text{ per cent. in original}$$

gas, and carbonic oxide in 30 c.c. equals (*vide* Equation 5).

$$0{\cdot}4 \text{ or } \frac{0{\cdot}4 \times 53}{30} = 0{\cdot}7 \text{ per cent. on original gas.}$$

Add CO absorbed by Cu_2Cl_2 = 31·7

Total = 32·4 per cent. CO in original gas.

Had the quantity of gas used for combustion over palladium been 14·05, as was used in second explosion, instead of 30 c.c. the contraction after passage over palladium would have been $\frac{30{\cdot}40 \times 14{\cdot}05}{30} = 14{\cdot}24$; and the quantity of CO_2 formed $\frac{0{\cdot}40 \times 14{\cdot}05}{30} = 0{\cdot}18$.

Subtracting these figures from those obtained in the second explosion :—

$$22{\cdot}6 - 14{\cdot}24 = 8{\cdot}36$$

and

$$5{\cdot}3 - 0{\cdot}18 = 5{\cdot}12,$$

the numbers, which are represented by x and y in equations (6) and (7) for calculating the values of methane and the higher paraffins, are obtained.

Then CH_4 in 14·05 c.c. $= \frac{4(8\cdot36) - 5(5\cdot12)}{3} = 2\cdot61$ c.c. or $\frac{2\cdot61 \times 53}{14\cdot05}$ $= 9\cdot84$ per cent. in original gas.

And C_2H_6 (or higher paraffins) in 14·05 c.c. $= \frac{4(5\cdot12) - 2(8\cdot36)}{3}$ $= 1\cdot25$ c.c. or $\frac{1\cdot25 \times 53}{14\cdot05} = 4\cdot71$ per cent. in original gas.

The carbon density (n) of the paraffins may be calculated by means of the equation

$$(8)\ n = \frac{3y}{2x - y},$$

$$\therefore \text{ Carbon density} = \frac{3(5\cdot12)}{2(8\cdot36) - 5\cdot12} = 1\cdot32,$$

average composition therefore

$$= C\,1\cdot32, H\,4\cdot64.$$

In order to determine the avèrage composition of the unsaturated hydrocarbon molecules, it is known that what takes place during the combustion of a hydrocarbon or hydrocarbons having the composition $CnHm$ may be represented by the following equation:—

$$CnHm + \left(n + \frac{m}{4}\right)O_2 = n(CO_2) + \frac{m}{2}(H_2O).$$

As the water vapour is condensed the contraction in volume

$$= 1 + \left(n + \frac{m}{4}\right) - n = 1 + \frac{m}{4}$$

The CO_2 formed $= n$.

If a = contraction in volume for x volumes of $CnHm$,

and $b = CO_2$ formed for x volumes of $Cn\ Hm$,

Then

$$(9)\ m = \frac{4(a - x)}{x}.$$

$$(10)\ n = \frac{b}{x}.$$

The amount taken for the first explosion was

$$\frac{12}{96\cdot9} = \cdot1237 \text{ of the original gas.}$$

It therefore contained

	Per cent.		c.c.
Illuminants	11·70 ×	·1237	= 1·45
Oxygen	0·50 ×	„	= 0·06
Carbonic oxide	31·70 ×	„	= 3·93
Residue	53·00 ×	„	= 6·56
			12·00

And the contraction and CO_2 formed after the second explosion was 22·6 c.c. and 5·30 c.c. respectively. The contraction and CO_2 formed, had

6·56 c.c. been taken instead of 14·05 c.c., would have been $\frac{22 \cdot 6 \times 6 \cdot 56}{14 \cdot 05}$ $= 10 \cdot 55$;

and $\frac{5 \cdot 30 \times 6 \cdot 56}{14 \cdot 05} = 2 \cdot 47$

Subtract these figures, plus those due to the 31·70 per cent. CO absorbed by Cu_2Cl_2, from the contraction and CO_2 formed in the first explosion, and the contraction and CO_2 due to the illuminants alone are obtained:—

		CO_2 formed c.c.	Contraction c.c.
3·93 c.c. CO	=	3·93	1·96
6·56 „ residue	=	2·47	10·55
		6·40	12·51
Results of first explosion	=	10·55	16·05
∴ 1·45 c.c. illuminants $CnHm$	=	4·15	3·54

And hence by equations (9) and (10) given above—

$$m = \frac{4(3 \cdot 54 - 1 \cdot 45)}{1 \cdot 45} = 5 \cdot 77,$$

$$n = \frac{4 \cdot 15}{1 \cdot 45} = 2 \cdot 86,$$

and the average composition of the illuminants is represented by $C_{2 \cdot 86} H_{5 \cdot 77}$.

The complete analysis and heating value of the gas is given below.

	Per cent.	B.T.U.
C_6H_6	= 0·4 × 3807·4	= 1,523
CO_2	= 2·7	
$(C_{2 \cdot 86}H_{5 \cdot 77})$	= 11·7 × (2·86 × 757 + 70)	= 26,149
O_2	= 0·5	
CO	= 32·4 × 323·5	= 10,481
H_2	= 35·6 × 326·2	= 11,613
CH_4	= 9·8 × 1009	= 9,888
C_2H_6	= 4·7 × 1764·4	= 8,292
N_2	= 2·2	
	100·0	67,946

or 679 B.T.U. per 1 cubic foot.

The Loss of Illuminating Power of 25- to 30-Candle Gas when mixed with Air. By Dr. E. G. Love. (American Gas Light Jour., lxix. 1898, 670.)

The author tabulates (see p. 214) the work of previous observers upon the deleterious effect produced by adding known percentages of air to coal gas.

It is well known that gas of low illuminating power is more injuriously affected than is gas of high illuminating power, and also that the deleterious effect of the air is less pronounced if the gas be consumed in an Argand burner than it is if a Batswing burner be used.

Percentage of Air in Mixture.	Andouin and Berard 1862. 12–14-Candle Gas. Flat Flame Burner.		H. Aitken, 1878. 27·8-Candle Gas.		B. W. Smith, 1885. 16·6-Candle Gas. Argand Burner.		Schilling and Ries, 1891. 19-Candle Gas. Flat Flame Burner.	
	Loss per cent.	Loss per cent. for 1 per cent. Air.	Loss per cent.	Loss per cent. for 1 per cent Air.	Loss per cent.	Loss per cent. for 1 per cent. Air.	Loss per cent.	Loss per cent. for 1 per cent. Air.
0·25	..	..	..	..	0·90	3·60	..	..
0·50	..	..	2·41	4·82	2·10	4·20	..	..
0·75	..	..	..	..	3·31	4·41	..	..
1·00	6	6·0	4·42	4·42	4·51	4·51	..	..
1·25	..	..	..	..	5·40	4·32	..	..
1·50	..	..	..	..	6·62	4·41	..	..
2·00	11	5·5	..	..	9·03	4·51	14·5	7·25
3·00	18	6·0	..	..	13·85	4·62	..	..
4·00	26	6·5	..	..	..	..	26·8	6·70
5·00	33	6·6	14·70	2·94	..	..	..	..
6·00	44	7·33	..	..	..	..	37·6	6·27
7·00	53	7·57	..	..	..	..	..	..
8·00	58	7·25	..	..	..	..	48·2	6·02
9·00	64	7·11	..	..	..	..	..	..
10·00	67	6·7	25·23	2·52	..	..	..	..
15·00	80	5·33	..	..	..	..	..	..
20·00	93	4·65	..	..	..	..	..	..
30·00	98	3·26	..	..	..	..	..	..
40·00	99	2·47	..	..	..	..	..	..
45·00	100	..	..	..	..	..	..	..

The author has made a series of tests—tabulated below—upon 25–27-candle water gas from a consumer's standpoint, viz. :—by employing a Bray Slit Union No. 7 burner, with a regulated consumption of 5 cubic feet per hour for all tests.

Percentage of Air in Mixture.	Loss of Illuminating Power.	Loss of Illuminating Power for 1 per cent. of Air.	Percentage of Air in Mixture.	Loss of Illuminating Power.	Loss of Illuminating Power for 1 per cent. of Air.
	Per cent.	Per cent.		Per cent.	Per cent.
2·82	5·72	2·03	17·65	44·30	2·51
4·94	10·08	2·04	19·84	51·19	2·58
5·40	11·24	2·08	21·56	56·69	2·63
8·51	18·04	2·12	22·22	58·88	2·65
8·95	19·06	2·13	24·16	64·51	2·67
9·62	21·16	2·20	27·69	72·82	2·63
10·40	23·24	2·24	31·30	80·44	2·57
11·20	26·66	2·38	32·95	83·36	2·53
12·35	29·02	2·35	34·53	87·02	2·52
12·81	30·48	2·38	37·50	90·37	2·41
15·25	37·66	2·47	40·79	93·82	2·30
16·98	42·28	2·49			

With water gas mixed with various percentages of air up to 5 per cent., it was scarcely possible for the eye to perceive any difference in the appearance of the flames.

A few tests were also made with an Argand burner, the results obtained showing the loss in illuminating power to be very small.

E. L. P.

Obituary.

Mr. John Methven, Resident Engineer of the Beckton works of the Gas Light and Coke Company, died at Brighton, April 4th, 1898.

He was born at the Coventry Gas-works, and on leaving school was apprenticed to the firm of Messrs. W. Mabon and Co., Manchester. His father, Mr. David Methven, was the well-known Engineer of the St. Pancras works of the Imperial Gas Company, and here John Methven acquired his first lessons in gas manufacture. On leaving St. Pancras he was for some little time with the Phœnix Gas Company, and was subsequently Secretary and Manager of the Redhill Gas Company, Engineer of the Gravesend Gas Company, and later Assistant-Engineer of the Windsor Street works of the Birmingham Gas Company. He left Birmingham on receiving the appointment of Assistant-Engineer to Mr. Robert Morton, at the Nine Elms works of the London Gas Company. This position he occupied until 1883, when, on the amalgamation of the undertaking with that of the Gas Light and Coke Company, he was appointed Resident Engineer at Nine Elms. He occupied this post until 1891, when he was entrusted with the onerous control of the Beckton works.

Mr. John Methven was an expert photometrician as well as an able engineer. In 1878 he brought out his well-known 2-candle screen, and three or four years later advocated a modification of it, by which the gas was carburetted before being consumed behind the standard slot. His best-known contribution to the technics of his profession was his paper upon Photometry, read before the Southern District Association of Gas Engineers in 1889, which contained a masterly denunciation of the action of the then Metropolitan Gas Referees. Later, he played an important part in exposing the unreliability of the proposed Dibden 10-candle standard, and in the action taken by this Institution in bringing the matter before the notice of the Board of Trade.

As an engineer Mr. Methven was always ready to place his broad knowledge of his work at the disposal of all with whom he came in contact or who sought his aid; and those who knew him most can best testify to his kindness of heart, his bonhommie, and the sincerity of his friendship.

He was one of the original Council of this Institution, and occupied the Presidential chair in 1893.

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